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**DATA REPORT OF SIX FREE-DRIFTING BUOYS
TRACKED BY THE EOLE SATELLITE IN THE WESTERN NORTH ATLANTIC OCEAN
IN THE AUTUMN OF 1972**

by J. W. Usry and J. W. Wallace



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16. Abstract This report presents the data from two free-drifting buoy missions conducted in the autumn of 1972. The buoys were deployed on the Continental Shelf east of the Chesapeake Light and were tracked by the French EOLE satellite. Two buoys drifted for 11 days during the first mission and four buoys drifted for 14 days during the second mission. Trajectory and water temperature data are presented in tabular and graphical form with a discussion of the accuracy.					
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Langley Research Center

SUMMARY

Two free-drifting buoy missions were conducted in the autumn of 1972. The buoys were tracked by the EOLE satellite via an active communications link which also communicated water temperature data at several depths along the drogue chain. Two buoys were deployed on October 26; buoy 1 drifted for six days, until October 31, and buoy 2 drifted for ten days, until November 4. Four buoys drifted for 14 days from December 1 to December 14. The buoys were deployed in the Continental Shelf waters east of the entrance to Chesapeake Bay. Trajectory and water temperature data are presented in tabular and graphical form with a discussion of the accuracy. Also presented are wind speed and direction at the Chesapeake Light, Oregon Inlet, and EB-01 environmental data buoy as determined by the National Weather Service during the times of the missions.

INTRODUCTION

The application of existing and emerging space technology and capabilities to societal needs and environmental problems is one of the major goals of NASA for the 1970's. As part of this program the Langley Research Center has been working with state and other federal agencies in studying the use of satellites and free-drifting buoy systems for remote measurements of current, temperature, salinity, sea state and other ocean and air-sea interface parameters. These data are needed to develop and validate analytical models which may be used for predicting the general ocean circulation and surface currents, and their transport of mass, heat, and nutrients.

The Chesapeake Bight extending from Delaware Bay to Cape Hatteras plays an important role in commerce, fishing, national defense, and recreation. Adjacent land areas have a large concentration of industry and people. Energy requirements have focused attention to this area as a potential oil source or location for energy production plants. The problems that have been identified in this area are typical of those in other coastal zone areas and include problems associated with location of offshore ports, power plants, outfalls for sewage disposal, and the dispersion of undesirable by-products of these facilities. An understanding of the circulation and physical structure of the shelf waters in this region is vital to the development of analytical models and to a predictive capability for general use in the coastal zones.

Historically, there are few measurements, using free-drifting buoys, of the circulation in this area. Most circulation data were deduced from random ship drift reports and contain uncertainties due to the difficulties of locating the ship's position. Only recently have oceanographers used free-drifting buoy systems to study kinematical flow properties such as divergence, vorticity, deformation (ref. 1), regional current patterns (ref. 2), and circulation patterns in the open ocean (ref. 3). The general surface circulation pattern in the Chesapeake Bight is southerly with magnitudes between 5-20 cm/sec. This trend can be modified, however, by wind conditions and freshwater runoff from the Delaware and Chesapeake Bays (ref. 4).

The purpose of this paper is to present data from two drift buoy missions conducted in October-November 1972 and December 1972. The duration of the first mission was 11 days, from October 26 to November 5, and the duration of the second mission was fourteen days, from December 1 to December 14. The buoys were identified by numbers 1, 2, 3, and 4. Buoys 1 and 2 were used on the October-November mission and buoys 1-4 were used on the December mission. Histories of the positions of each buoy and water temperatures were obtained via satellite. These data are presented in tabular and graphical form without an analysis. Also presented are estimates of the accuracy of these data.

BUOY DESCRIPTION

An artist sketch and photographs of the buoy system are shown as figures 1(a), 1(b), and 1(c), and a sketch with pertinent dimensions is shown as figure 2. The system had four major components: the floatation disk, instrument box, connector chain, and drogue plates. The system floated so that the top half of the floatation disk was above the water line and the top of the drogue plates was 5 (or 30) meters below the water line. The ratio of the drag area of the drogue plates to the drag area of the floatation disk and instrument box, below the water line, was six to one. The system mass was 254 kg.

The floatation disk had a diameter of 0.914 m, a maximum thickness at the center of 0.102 m, and a minimum thickness of 0.064 m at the periphery. A lifting bridle, used during deployment and retrieval operations, was attached to the disk and extended 0.732 m above the disk when in a raised position. The antenna used in the communications link with the satellite was mounted on the disk as shown in the photographs.

The instrument box had a length, width, and depth of 0.584, 0.541, and 0.483 m, respectively. The box housed the satellite transponder, power supply, radio beacons, relays, oscillators, and other related electronics. Three floatation blocks were mounted on the sides and four support legs were attached to the bottom. An access hatch allowed entry into the instrument compartment for checkout purposes.

A drogue consisting of crossed drag plates was suspended below the instrument box using a 0.63 cm (1/4 inch) galvanized chain. The chain was attached to a swivel at the top of the drag plates. Temperature sensors

were mounted along the length of the chain as illustrated in figure 1(c). The chain connections were designed so that different length chains could be installed in the field. The drag plates were 1.524 m square. The rods kept the plates at right angles respective to one another and lead ballast mounted on the plates kept the plates in line with the floatation disk.

SYSTEMS DESCRIPTION

The Centre National D'Etudes Spatiales (CNES) of France designed and built the EOLE satellite launched by the NASA at Wallops Island, Virginia on August 16, 1971, using the NASA Scout Vehicle. The satellite was placed in a circular orbit at 800 km with an inclination of 50° to the equator and a period of 103 minutes. The purpose of the satellite was to observe the movements of a fleet of balloons floating at a constant altitude in the Southern Hemisphere. The satellite became available for use by other experimenters upon completion of that mission. The Langley Research Center proposed using the navigation and data collection satellite systems to track free-drifting buoys on the Continental Shelf of the Western North Atlantic and to measure the temperature of the water at selected depths. The EOLE satellite system is described in reference 5.

A functional diagram of the navigation and data collection system used in the free-drifting buoy program is shown in figure 3, and photographs of some of the buoy system components are shown as figure 4. The CNES developed a transponder-antenna system for use on free-drifting buoys which accepted four in situ data measurements (see fig. 4). The antenna (see fig. 1) was a cavity-backed spiral which allowed transmission to the satellite at low elevation angles.

The satellite continuously transmitted on a frequency at 464 MHz. Upon entering the zone of communications with the buoy, a two-way, phase-coherent link was established. The measured data were transmitted via the oscillator frequencies modulated onto a 402 MHz carrier. After transmission to the satellite, these data were stored onboard and later telemetered to ground receiving stations. The two-way, phase-coherent link allows a precise measurement of the propagation delay and Doppler shift. With these data, an accurate measurement of time, and the orbital parameters of the satellite, the buoy position can be determined. The CNES has estimated that the position can be determined with an accuracy of 1 to 2 km (ref. 6). The buoy transponder transmission period is 583 ms but since the satellite interrogates continuously, data will be transmitted for several minutes (as long as the satellite is in the field of transmission). Thus, nearly continuous data may be received during one orbit of the satellite. This provides several data points, both temperature and position, while the buoy is essentially in one position. From these data the mean position and temperature for one orbital pass were estimated.

Each buoy on both missions carried two radio beacons. These are shown mounted on the instrument tray in figure 4(c). One of the beacons transmitted continuously from the time of deployment to recovery. The second beacon could

be turned on through the communications link with the satellite, if the primary beacon failed. The beacons were search and rescue radio beacons of the type used in the Gemini training program, and transmitted on a frequency of 235 MHz. Wire antennas were located on top of the buoy as shown in figure 1(c). The antenna was a quarter-wavelength (at 235 MHz) wire coated with fiberglass and teflon tape.

Ocean water temperatures were measured using variable resistance thermistors on all of the buoys on both missions. Their thermistors were designed to have a rapid and large change in resistance for a relatively small change in temperature.

Data Presentation and Accuracy

Buoys 1 and 2 were deployed southeast of Wallops Island, Virginia at approximately 37.3° N, 74.7° W and 8 km apart on October 26 and data were first received on October 28. Buoy 1, drogued at 30 meters, drifted southwest and went aground after five days about 38 km from the point of deployment. The buoy was recovered and returned to Langley for repairs and preparation for redeployment. Buoy 2, drogued at 5 meters, drifted south, then east, intercepted the Gulf Stream, and was recovered 380 km east of Cape Charles.

Buoys 1-4 were deployed near Cape Henry about 2 km apart on a west-to-east line beginning 8 km from shore. The order of deployment from the shoreline was 4, 1, 2, and 3. Buoys 1, 2, and 4 drifted northeast across the Chesapeake Bay entrance, reversed direction, drifted back near the point of deployment, and from this point drifted south. Buoy 3 drifted east about 30 km, meandered briefly, and drifted south. All buoys were recovered near Cape Hatteras.

Histories of the position and temperature data, and wind data from the National Weather Service, are listed in Tables I and II. Water temperature was measured at 5 and 30 meters on buoy 1 and 0 and 5 meters on buoy 2. During the December mission, water temperatures were measured at a depth of 2 meters on all buoys. The position data were converted to rectangular coordinates from a reference point located at latitude 36° N and longitude 76° W where X, in km, is equal to (76.0 - longitude) times 89.014, and Y, in km, is equal to (latitude - 36.0) times 110.975. These data are listed in Tables I(a) and I(b) for the October/November mission and II(a) and II(b) for the December

mission. The distance from the reference point, R ($R = \sqrt{X^2 + Y^2}$) and direction from north, θ ($\theta = \arctan X/Y$), are also listed in these tables. Wind speed and direction measured by the National Weather Service at the Chesapeake Light (36.9° N, 75.7° W), Oregon Inlet (35.8° N, 75.5° W), and the environmental data buoy EB-01 (36.5° N, 73.5° W) are listed in Tables I(c) and II(c). The convention for wind direction at Chesapeake Light and Oregon Inlet is taken as the direction from which the wind blows. For buoy EB-01 the wind azimuth is the angle, from north, from which the wind blows.

Trajectories and histories of the data listed in the tables are presented graphically in figures 5-9. The locations of the deployment positions for the two missions relative to the coastline are shown in figure 5 with histories of the wind speed and direction at Chesapeake Light, EB-01, and Oregon Inlet. Trajectories are plotted in figures 6 and 8. Lines between data points

are included for clarity and do not necessarily represent the trajectory. Data gaps with less than 10 hours duration usually occurred because of the orbit of the satellite and gaps with larger time intervals usually occurred due to the loss of data.

Accuracy

The accuracy of the position and temperature data is dependent upon several error sources associated with orbital parameters, event timing, instrument and electrical components on the buoy and on the satellite, and data handling. Specific error sources contributing to uncertainties in the position data are discussed in references 6 and 7. Tests to determine the accuracy of the position data were conducted after completion of the missions reported here and after buoys 3 and 4 were lost during another experiment. For this paper, the accuracy of the position data was estimated by locating buoys 1 and 2 and two additional buoys, 5 and 6, at a known point (latitude and longitude) at Langley and having the satellite interrogate the buoys for several days. Similarly, buoy 1 was placed in a controlled temperature environment and interrogated to determine the accuracy of the temperature data.

The satellite interrogates the buoys continuously so that several position points are obtained during one pass. The average of these positions is assumed to be the best location for the pass. These data are plotted in figure 10 as the difference (d) in the actual location and the average location, as determined by the satellite versus the angle (ψ) between lines from the Earth's center to the buoy and to the point on the satellite ground track which is the point of closest approach to the buoy. Buoys 1, 2, 5, and 6 were interrogated for 5.5, 7, 7, and 4 days, and 27, 34, er, and 17 location points were obtained, respectively.

From these data the standard deviation in ΔX and ΔY and a 50 percent circular probable error (CPE) were estimated. These data are shown in figure 11. It is apparent that a systematic error in the order of 1 to 1.5 km exists for buoys 1, 2, and 5. The error is larger for buoy 6, probably because of the scarcity of points. Also, it appears that the random error (CPE) is buoy dependent as might be expected (ref. 6 makes this point also) and is 1.4, 1.7, 2.3, and 1.6 km, respectively, for buoys 1, 2, 5, and 6.

The accuracy of the temperature data was buoy dependent since the sensors (thermistor-oscillator combination) were unique to each buoy, but errors associated with the satellite and data handling were common to all buoys. Since the buoys were usually deployed in close proximity to one another during a mission and cross checks were possible, only buoy 1 was used in the test to ascertain the accuracy of the temperature data. Each buoy carried four sensors or four data channels. In some cases the sensors were calibrated to measure different temperature ranges and in others the measurements were redundant. The thermistors were designed to operate below 75° C and to be accurate to $\pm 0.1^\circ$ C over a range from 0° C to 70° C. The data in Table III indicate that the uncertainty due to all errors was probably $\pm 0.3^\circ$ C. Additional interrogations would have provided a better estimate of this uncertainty.

CONCLUDING REMARKS

Two free-drifting buoy missions were conducted in the autumn of 1972 in the Western North Atlantic Ocean and primarily in the Continental Shelf waters between Cape Charles and Cape Hatteras. Two buoys drifted for 11 days, from October 26 to November 5, and four buoys drifted for 14 days, from December 1 to December 14. Trajectory data and water temperature along the trajectory were obtained using the French EOLE satellite. These data have been presented in tabular and graphical form with a discussion of the accuracy.

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TABLE I.- LIST OF DATA, OCT.-NOV. 1972

(a) Buoy 1

Time Mo/Day/Hr	Elapsed time, hr	Lat., North deg.	Long., West deg.	T,5m °C	T,30m °C	X, km	Y, km	R, km	Azimuth, θ deg.
102806	0.0	37.15	74.78	14.8	14.2	108.2	127.5	167.2	40.3
102808	1.8	37.14	74.79	14.8	14.1	108.1	126.8	166.6	40.4
102809	3.5	*	*	14.8	14.3	*	*	*	*
102811	5.3	37.12	74.82	14.9	14.2	104.9	124.7	163.0	40.1
102900	18.2	37.13	74.83	*	*	104.1	126.0	163.4	39.6
102902	19.9	37.12	74.84	15.3	14.3	103.6	124.5	162.0	39.8
102904	21.7	37.12	74.84	15.4	14.3	103.6	124.5	162.0	39.8
102905	23.5	37.11	74.84	15.3	14.2	103.0	123.4	160.7	39.8
102907	25.3	37.10	74.85	15.5	14.3	102.2	122.4	159.5	39.9
102909	27.0	*	*	15.4	14.2	*	*	*	*
102911	28.8	37.08	74.88	15.3	14.2	99.7	120.2	156.2	39.7
103007	48.7	37.06	74.93	16.0	14.7	95.6	117.7	151.7	39.1
103008	50.5	37.07	74.91	15.7	14.7	97.0	119.1	153.6	39.2
103010	52.2	37.03	74.94	15.5	14.7	93.9	114.0	147.7	39.5
103102	68.6	36.92	74.92	*	*	95.8	102.1	140.0	43.2
103106	72.2	36.87	74.94	15.4	14.8	94.4	97.0	135.3	44.2
103108	73.9	36.88	74.94	15.3	14.7	94.5	97.4	135.8	44.1
103110	75.7	36.84	74.97	15.3	15.2	91.9	93.4	131.0	44.5

*
No data.

TABLE I.- LIST OF DATA, OCT.-NOV. 1972 - Continued

(b) Buoy 2

Time	Elapsed	Lat.,	Long.,	T,0m	T,5m	X,	Y,	R,	Azimuth,
		North	West						θ
Mo/Day/Hr	Time, hr	deg.	deg.	°C	°C	km	km	km	deg.
102805	0.0	37.00	74.66	16.3	*	119.5	111.4	163.4	47.0
102808	1.8	36.99	74.64	16.2	*	121.1	109.4	163.2	47.9
102811	5.3	36.95	74.63	16.2	*	121.8	105.8	161.3	49.0
102900	18.2	36.82	74.58	16.5	16.9	126.8	90.6	155.9	54.5
102902	19.9	36.78	74.48	16.5	16.6	135.0	86.7	160.5	57.3
102904	21.7	36.78	74.48	16.5	17.4	135.0	86.7	160.5	57.3
102905	23.5	36.73	74.48	16.6	18.5	134.9	81.6	157.7	58.8
102907	25.3	36.71	74.50	16.6	16.9	133.8	78.7	155.2	59.5
102911	28.8	36.63	74.53	16.6	16.5	131.1	69.8	148.5	62.0
103007	48.8	36.32	74.46	17.4	17.3	137.4	35.6	142.0	75.5
103008	50.5	36.32	74.44	17.6	17.6	138.5	35.0	142.8	75.8
103010	52.2	36.26	74.49	17.7	17.6	134.9	29.0	137.9	77.9
103106	72.2	36.19	74.32	17.0	17.4	149.7	20.9	151.2	82.1
103108	73.9	36.22	74.29	17.1	18.2	152.6	24.5	154.5	80.9
103110	75.7	36.21	74.28	17.7	18.3	153.1	23.3	154.9	81.3
110106	95.6	36.40	73.93	17.9	17.9	184.2	44.7	189.5	76.4
110107	97.4	36.43	73.91	17.7	17.9	186.2	47.6	192.2	75.7
110109	99.1	36.42	74.02	17.9	17.9	175.8	47.2	182.0	75.0
110200	113.8	36.58	73.61	18.8	18.7	212.5	64.6	222.1	73.1
110201	115.5	36.62	73.59	18.7	18.6	214.5	69.1	225.4	72.1
110203	117.3	36.61	73.54	18.5	18.5	219.2	67.8	229.4	72.8
110205	119.1	36.63	73.50	20.5	19.1	222.4	70.0	233.2	72.5
110207	120.9	36.67	73.46	19.5	19.1	226.4	74.0	238.2	71.9
110209	122.6	36.66	73.45	19.0	18.8	226.7	73.2	238.3	72.1
110304	142.5	36.85	72.86	19.2	19.2	279.2	94.1	294.7	71.4
110308	146.1	36.85	72.75	19.1	19.1	289.1	93.9	304.0	72.0
110323	160.7	36.96	72.07	19.4	19.5	350.0	106.3	365.8	73.1
110400	162.4	37.01	71.99	19.6	19.6	358.9	112.5	374.3	72.5
110402	164.2	37.03	71.89	19.6	19.5	366.3	113.7	383.5	72.7
110404	166.0	37.06	71.81	19.5	19.5	373.4	117.2	391.4	72.6
110406	167.8	37.10	71.75	19.4	19.3	378.5	121.7	397.6	72.2
110407	169.5	37.12	71.72	19.4	19.4	381.1	123.8	400.7	72.0
110409	171.3	37.16	71.65	*	*	387.4	128.7	408.2	71.6

* No data.

TABLE I.- LIST OF DATA, OCT.-NOV. 1972 - Continued

(c) Wind Data

Time	Chesapeake Light		Oregon Inlet		EB-01	
Mo/Day/Hr	Direction	Speed kts	Direction	Speed kts	Azimuth deg	Speed kts
102803	ENE	10	NE	15	*	
102806	SE	10	NE	15		
102809	E	20	NE	18		
102812	SE	10	NE	15		
102815	SE	26	SW	12		
102818	SE	12	SW	15		
102821	SE	16	SSW	10		
102900	W	10	NE	10		
102903	W	10	SW	12		
102906	NW	10	Calm			
102909	W	10	SW	5		
102912	SW	10	Calm			
102915	SW	8	Calm			
102918	WSW	4	SW	5		
102921	Calm		Calm			
103000	WSW	2	Calm			
103003	NW	20	Calm			
103006	NNW	26	NE	10		
103009	NNW	20	NE	15		
103012	NNW	20	NE	18		
103015	NNW	16	NE	18		
103018	N	12	NE	20		
103021	NE	5	NE	20		
103100	N	8	NE	15		
103103	NE	8	NE	15		
103106	NNE	10	NE	15		
103109	NNE	10	NE	15		
103112	NNE	10	NE	15		
103115	N	10	NE	18		
103118	N	8	ENE	20	8	8
103121	NNE	1	NE	20	9	13

* No data.

TABLE I.- LIST OF DATA, OCT.-NOV. 1972 - Concluded

(c) Wind Data.- Concluded

Time	Chesapeake Light		Oregon Inlet		EB-01	
Mo/Day/Hr	Direction	Speed kts	Direction	Speed kts	Azimuth deg	Speed kts
110100	N	7	NE	20	24	12
110103	NE	8	NE	12	31	11
110106	NNE	6	NE	10	*	*
110109	NE	4	NE	10	29	8
110112	NNE	6	NE	15	28	8
110115	NE	12	NE	15	29	10
110118	NNE	10	NE	10	29	13
110121	ENE	8	NE	15	13	9
110200	E	4	NE	15	36	7
110203	ENE	9	Calm		54	6
110206	ENE	10	Calm		92	10
110209	E	10	Calm		169	14
110212	SE	10	Calm		199	19
110215	S	8	SW	5	184	20
110218	Se	10	W	5	163	10
110221	SE	16	SW	8	247	7
110300	SSE	18	SW	5	76	2
110303	S	20	SW	5	233	18
110306	S	12	SW	5	237	23
110309	S	20	SW	5	242	27
110312	S	20	SW	5	244	36
110315	SSW	18	SW	10	239	34
110318	SSW	12	SW	10	241	38
110321	S	7	SW	10	248	43
110400	N	6	SW	10	255	25
110403	NE	20	Calm		59	32
110406	NE	18	SW	10	65	6
110409	E	30	SW	10	77	12
110412	NNE	24	SW	10	53	38
110415	NE	30	SW	8	66	28
110418	NNE	6	SW	5	90	44
110421	NNW	6	SW	5	257	11
110500	NW	14	SW	8	57	30
110503	NNW	16	NE	10	303	14

* No data.

TABLE II.- LIST OF DATA, DEC. 1972

(a) Buoy 1

Time, Mo/Day/Hr	Elapsed Time, hr	Lat. North deg.	Long. West deg.	T,2m °C	X, km	Y, km	R, km	Azimuth θ deg.
120116	0	36.86	75.86	10.3	12.4	95.0	95.8	7.4
120118	1.7	36.84	75.84	10.2	13.9	92.9	93.9	8.5
120120	3.5	36.80	75.87	10.2	11.2	89.2	89.9	7.2
120122	5.3	36.80	75.87	10.3	11.2	89.2	89.9	7.2
120212	19.9	36.89	75.79	9.6	18.6	98.9	100.6	10.7
120214	21.7	36.90	75.75	9.7	21.9	99.4	101.8	12.4
120216	23.4	36.92	75.73	9.7	23.8	102.7	105.4	13.0
120218	25.8	36.93	75.69	9.9	27.1	103.3	106.8	14.7
120219	27.0	36.94	75.68	9.9	28.6	104.5	108.4	15.3
120221	29.0	36.90	75.73	10.1	24.1	99.9	102.7	13.6
120319	50.5	37.07	75.61	10.3	34.4	119.2	124.1	16.1
120322	54.0	37.09	75.64	10.1	31.7	120.6	124.7	14.7
120411	66.8	37.09	75.65	10.1	31.1	121.3	125.2	14.4
120416	70.4	37.16	75.61	10.2	34.3	125.3	129.9	15.3
120417	72.1	37.16	75.53	10.3	42.2	129.2	135.9	18.1
120418	73.9	37.12	75.60	10.2	35.5	124.1	129.1	16.0
120420	75.7	37.15	75.58	10.4	37.5	127.4	132.8	16.4
120422	77.4	37.10	75.63	10.6	32.7	122.1	126.4	15.0
120511	90.3	37.04	75.66	*	30.5	115.7	119.7	14.8
120516	95.6	37.04	75.66	10.6	30.4	115.9	119.8	14.7
120518	97.4	37.04	75.66	10.8	30.7	115.5	119.5	14.9
120521	100.9	37.04	75.67	*	29.4	114.9	118.6	14.3
120614	117.3	37.09	76.66	10.7	30.1	120.4	124.1	14.0

* No data.

TABLE II.- LIST OF DATA, DEC. 1972 - Continued

(a) Buoy 1 - Concluded

Time Mo/Day/Hr	Elapsed Time, hr	Lat. North deg	Long. West deg	T,2m °C	X, km	Y, km	R, km	Azimuth θ deg
120616	119.1	37.08	76.65	10.7	31.5	120.1	124.1	14.7
120617	120.8	37.08	76.64	10.8	32.0	120.1	124.3	14.9
120619	122.6	37.08	75.64	10.8	31.8	119.7	123.9	14.9
120717	144.3	36.94	75.70	10.8	26.6	104.2	107.6	14.3
120720	147.8	36.89	75.74	10.8	22.9	99.1	101.7	13.0
120811	162.5	36.87	75.82	10.6	16.1	96.3	97.7	9.5
120813	164.2	36.89	75.84	10.6	14.2	99.1	100.1	8.2
120814	166.0	36.89	75.84	10.8	14.2	98.3	99.3	8.2
120816	167.8	36.89	75.87	10.8	11.8	98.7	99.4	6.8
120818	169.5	36.87	75.88	10.8	10.4	96.3	96.9	6.2
120820	171.3	36.87	75.88	10.9	10.4	96.3	96.9	6.2
120822	173.0	36.87	75.87	*	11.8	96.7	97.4	7.0
120910	185.9	36.86	75.83	10.5	15.2	95.2	96.4	9.1
120914	189.4	36.87	75.83	10.5	15.1	96.3	97.5	8.9
121013	212.9	36.88	75.75	11.0	22.3	97.8	100.3	12.8
121020	220.0	36.90	75.78	*	19.9	100.0	101.9	11.2
121212	259.8	36.57	75.78	10.4	19.1	63.7	66.5	16.7
121214	261.6	36.56	75.79	*	19.0	61.8	64.7	17.1
121219	266.9	36.48	75.78	*	19.2	53.8	57.2	19.7
121308	280.0	36.25	75.71	10.2	25.5	27.3	37.3	43.0
121310	281.5	38.21	75.68	10.3	28.0	23.5	36.6	50.0
121413	308.5	35.26	75.26	16.1	72.8	-82.0	109.7	138.4

* No data.

TABLE II.- LIST OF DATA, DEC. 1972 - Continued

(b) Buoy 2

Time Mo/Day/Hr	Elapsed Time, hr	Lat. North deg.	Long. West deg.	T, 2m °C	X, km	Y, km	R, km	Azimuth, θ deg.
120117	0.0	36.87	75.83	10.7	15.0	96.2	97.4	8.9
120118	1.8	36.85	75.82	10.7	16.0	94.2	95.6	9.7
120120	4.5	36.82	75.85	10.6	13.6	90.6	91.6	8.6
120122	5.3	36.82	75.85	10.6	13.6	90.6	91.6	8.6
120212	19.9	36.89	75.74	10.6	23.3	99.0	101.7	13.3
120214	21.7	36.90	75.71	10.5	26.0	99.5	102.9	14.6
120216	23.5	36.92	75.68	10.4	28.1	101.9	105.7	15.4
120218	25.2	36.92	75.67	10.4	29.8	102.3	106.6	16.2
120220	27.0	36.93	75.65	10.5	31.2	103.3	107.9	16.8
120221	28.8	36.90	75.70	10.5	26.8	99.7	103.2	15.0
120319	50.5	37.04	75.60	10.5	35.8	115.0	102.4	17.3
120322	54.0	37.05	75.63	10.2	33.1	116.4	121.0	15.9
120411	66.8	37.05	75.66	10.2	30.4	117.4	121.3	14.5
120415	70.4	37.08	75.63	10.6	32.9	119.5	124.0	15.4
120417	72.1	37.07	75.62	10.5	33.6	118.7	123.4	15.8
120418	73.9	37.07	75.63	10.3	33.4	118.5	123.1	15.7
120420	75.7	37.09	75.61	10.3	34.4	121.0	125.8	15.9
120422	77.4	37.06	75.66	10.3	30.7	117.4	121.4	14.7
120511	90.3	37.01	75.66	10.6	28.7	112.0	115.6	14.4
120516	95.6	37.01	75.68	10.6	28.8	111.8	115.4	14.5
120618	97.4	37.00	75.67	10.5	29.1	111.3	115.1	14.7
120621	100.9	37.00	75.68	10.6	28.4	111.0	114.6	14.4
120614	117.3	37.05	75.68	10.6	28.2	116.4	119.8	13.6

TABLE II.- LIST OF DATA, DEC. 1972 - Continued

(b) Buoy 2 - Concluded

Time Mo/Day/Hr	Elapsed Time, hr	Lat. North deg.	Long. West deg.	T,2m °C	X, km	Y, km	R, km	Azimuth, θ deg.
120616	119.1	37.04	75.07	10.5	29.4	115.9	119.5	14.2
120617	120.8	37.04	75.66	10.5	30.0	115.7	119.6	14.5
120619	122.6	37.05	75.67	10.6	29.8	116.2	120.0	14.4
120621	124.3	37.05	75.67	10.6	29.8	116.2	120.0	14.4
120715	142.5	36.94	75.72	10.7	25.0	104.0	106.9	13.5
120717	144.3	36.90	75.74	10.7	22.9	100.2	102.8	12.9
120719	146.1	36.85	75.78	10.8	19.2	94.8	96.7	11.5
120720	147.8	36.85	75.78	10.8	19.2	94.8	96.7	11.5
120811	163.0	36.79	75.84	10.8	14.6	88.1	89.3	9.4
120812	164.3	36.81	75.85	11.2	13.7	89.7	90.7	8.7
120814	166.0	36.79	75.84	10.8	13.9	88.0	89.1	9.0
120816	167.8	36.78	75.85	10.8	13.1	87.0	88.0	8.6
120818	169.5	36.78	75.88	10.8	10.9	83.9	84.6	7.4
120820	171.3	36.76	75.88	10.8	10.9	83.9	84.6	7.4
120821	173.0	36.77	75.88	*	12.0	84.9	85.7	8.1
120910	185.9	36.74	75.87	10.9	11.8	81.9	82.8	8.2
120921	196.5	36.75	75.88	11.2	11.0	83.1	83.8	7.6
121013	212.9	36.73	75.81	11.2	17.1	80.7	82.5	12.0
121020	220.0	36.74	75.81	*	16.6	82.6	84.2	11.3
121212	254.8	36.14	75.67	11.0	29.8	15.9	33.8	62.0
121214	261.6	36.09	75.67	*	29.4	10.2	31.1	70.8
121219	266.9	36.00	75.62	11.0	33.6	-.4	33.6	90.8
121413	308.6	36.43	75.37	11.8	56.2	-63.7	84.9	138.6
121417	312.1	35.45	75.32	15.0	60.2	-61.5	86.0	135.6
121418	314.0	35.64	75.34	12.5	59.1	-39.7	71.2	123.9

* No data.

TABLE II.- LIST OF DATA, DEC. 1972 - Continued

(c) Buoy 3

Time Mo/Day/Hr	Elapsed Time, hr	Lat. North deg.	Long. West deg.	T,2m °C	X, km	Y, km	R, km	Azimuth, θ deg.
120117	0.0	36.86	75.80	10.9	17.6	95.2	96.8	10.5
120118	1.7	36.84	75.79	11.1	18.8	93.1	95.0	11.4
120120	3.5	36.82	75.80	10.8	17.5	91.3	93.0	10.9
120122	5.3	36.82	75.80	11.1	17.5	91.3	93.0	10.9
120200	7.0	36.90	75.81	11.0	16.7	99.5	100.9	9.5
120212	19.9	36.67	75.88	11.1	28.5	96.8	100.9	16.4
120214	21.6	36.88	75.65	11.1	31.0	97.3	102.1	17.7
120216	23.5	36.67	75.61	10.8	34.3	96.4	102.3	19.6
120218	25.2	36.86	75.60	11.3	35.3	95.9	102.2	20.2
120220	27.0	36.87	75.60	11.1	35.7	96.7	103.0	20.3
120221	28.7	36.86	75.63	11.2	33.2	95.0	100.6	19.3
120319	50.5	36.92	75.47	11.3	47.1	102.7	112.9	24.6
120322	53.9	36.93	75.49	11.3	45.2	103.7	113.1	23.6
120411	66.8	36.93	75.53	11.1	42.2	102.9	111.2	22.3
120416	70.4	36.94	75.50	11.3	44.7	104.2	113.4	23.2
120417	72.1	36.93	75.49	11.3	45.3	103.3	112.8	23.7
120418	73.9	36.92	75.50	11.4	44.9	102.2	111.6	23.7
120420	75.7	36.93	75.50	11.3	44.3	102.9	112.0	23.3
120422	77.4	36.91	75.52	11.3	42.3	101.5	110.0	22.6
120511	90.3	36.86	75.55	*	40.2	94.9	103.1	23.0
120516	95.6	36.83	75.53	11.5	41.6	92.4	101.4	24.2
120518	97.4	36.83	75.54	11.8	41.1	91.7	100.5	24.2
120521	100.9	36.82	75.56	12.1	39.5	90.6	98.8	23.6
120614	117.3	36.81	75.57	11.7	38.7	89.9	97.9	23.2
120616	119.0	36.81	75.55	11.9	40.0	89.4	98.0	24.1
120617	120.8	36.80	75.54	11.9	40.8	89.2	98.1	24.6
120619	122.6	36.80	75.55	12.0	40.0	88.3	97.0	24.3
120621	124.3	36.80	75.55	12.0	40.0	88.3	97.0	24.3
120713	140.7	36.65	75.53	*	41.5	71.9	83.0	30.0
120715	142.5	36.61	75.54	11.8	40.9	67.9	79.3	31.1

* No data.

TABLE II.- LIST OF DATA, DEC. 1972 - Continued

(c) Buoy 3 - Concluded

Time Mo/Day/Hr	Elapsed Time, hr	Lat. North deg.	Long. West deg.	T,2m °C	X, km	Y, km	R, km	Azimuth, θ deg.
120717	144.3	36.55	75.54	11.7	40.8	64.1	76.0	32.4
120719	146.0	36.53	75.56	11.7	39.2	58.3	70.2	33.9
120720	147.8	36.53	75.56	13.2	39.2	58.3	70.2	33.9
120811	162.4	36.44	75.57	11.7	37.9	49.3	62.2	37.6
120813	164.3	36.44	75.57	11.9	38.1	48.4	61.6	38.2
120814	166.0	36.43	75.57	11.9	38.2	47.4	60.9	38.9
120816	167.8	36.41	75.57	12.0	37.9	45.7	59.4	39.7
120818	169.5	36.38	75.59	11.8	36.8	42.5	56.2	40.9
120820	171.3	36.38	75.59	12.0	36.8	42.5	56.2	40.9
120910	185.9	36.31	75.56	12.1	39.3	34.6	52.4	48.7
120914	189.5	36.30	75.55	12.1	40.3	33.3	52.3	50.5
120921	196.5	36.30	75.57	*	38.5	33.1	50.7	49.3
121013	212.9	36.24	75.52	12.0	43.1	27.2	50.9	57.7
121020	220.0	36.24	75.51	*	44.0	26.9	51.5	58.6
121212	259.8	35.82	75.48	12.3	48.2	-20.2	52.3	112.7
121219	266.9	35.77	75.46	12.5	47.7	-26.1	54.4	118.7
121308	279.8	35.62	75.41	12.4	52.7	-41.7	67.2	128.4
121310	281.5	35.69	75.38	12.2	54.9	-45.1	71.0	129.4
121312	283.3	35.57	75.38	12.5	56.9	-48.3	74.6	130.3
121314	285.0	35.54	75.36	12.3	57.1	-51.6	77.0	132.1
121315	286.8	35.52	75.37	12.4	56.3	-53.8	77.9	133.7
121319	290.3	35.51	75.38	12.4	55.5	-54.5	77.7	134.5
121413	308.5	35.46	75.32	12.6	60.9	-60.0	85.5	134.6
121417	312.1	35.43	75.33	13.2	59.5	-62.7	86.4	136.5

* No data.

TABLE II.- LIST OF DATA, DEC. 1972 - Continued

(d) Buoy 4

Time Mo/Day/Hr	Elapsed Time, hr	Lat. North deg.	Long. West deg.	T,2m °C	X, km	Y, km	R, km	Azimuth, θ deg.
120117	0.0	36.86	75.89	10.6	10.1	95.4	96.0	6.1
120118	1.7	36.84	75.88	10.3	11.0	92.9	93.5	6.8
120120	3.5	36.80	75.91	10.1	8.3	88.7	89.1	5.3
120122	5.3	36.80	75.91	9.9	8.3	88.7	89.1	5.3
120212	19.9	36.86	75.84	9.5	13.9	95.5	96.6	8.3
120214	21.6	36.86	75.81	9.5	17.2	95.4	97.0	10.2
120216	23.5	36.87	75.78	9.6	19.2	97.0	98.9	11.2
120218	25.2	36.87	75.76	9.8	21.2	96.5	98.8	12.4
120220	27.0	36.86	75.75	9.8	22.1	95.9	98.4	13.0
120318	50.5	36.98	75.67	10.2	29.0	108.8	112.6	14.9
120322	53.9	36.98	75.69	10.2	27.7	108.8	112.2	14.3
120415	70.4	37.01	75.74	9.6	23.3	112.2	114.6	11.7
120417	72.1	37.01	75.73	9.9	24.3	111.9	114.5	12.3
120418	73.9	37.00	75.72	10.0	24.6	111.3	114.0	12.4
120420	75.7	37.03	75.50	10.1	26.3	114.2	117.2	13.0
120422	77.4	36.99	75.74	10.2	22.8	110.3	112.6	11.7
120511	90.3	36.96	75.78	10.2	19.8	107.0	108.8	10.5
120516	95.6	36.98	75.79	10.5	18.6	109.0	110.6	9.7
120518	97.4	36.98	75.78	10.6	19.7	108.5	110.3	10.3
120521	100.8	36.98	75.77	10.9	20.3	108.4	110.3	10.6
120614	117.3	37.05	75.75	10.5	21.9	116.7	118.8	10.6
120616	119.0	37.04	75.74	10.6	22.8	115.9	118.1	11.1
120617	120.8	37.04	75.73	10.8	24.1	115.6	118.1	11.8
120619	122.6	37.05	75.74	10.8	23.1	116.6	118.9	11.2

TABLE II.- LIST OF DATA, DEC. 1972 - Continued

(d) Buoy 4 - Concluded

Time Mo/Day/Hr	Elapsed Time, hr	Lat. North deg.	Long. West deg.	T,2m °C	X, km	Y, km	R, km	Azimuth, θ deg.
120621	124.3	37.05	75.75	10.9	23.1	116.6	118.9	11.2
120713	140.8	36.99	75.76	10.7	21.5	110.4	112.5	11.0
120715	142.5	36.96	75.77	11.0	20.2	107.0	108.9	10.7
120717	144.3	36.94	75.78	10.9	19.1	104.2	105.9	10.4
120719	146.1	36.89	75.81	10.9	17.1	98.9	100.3	9.8
120720	147.8	36.89	75.81	10.9	17.1	98.9	100.3	9.8
120811	162.4	36.87	75.87	10.4	11.8	96.2	96.9	7.0
120813	164.3	36.88	75.87	10.4	11.4	97.4	98.1	6.7
120814	166.0	36.88	75.89	10.8	10.1	97.1	97.6	6.0
120816	167.8	36.88	75.90	10.8	9.3	97.1	97.6	5.5
120818	169.5	36.85	75.92	10.8	7.6	94.1	94.4	4.6
120820	171.3	36.85	75.92	11.1	7.6	94.1	94.4	4.6
120910	185.9	36.82	75.87	10.6	11.2	91.3	92.0	7.0
120914	189.5	36.84	75.87	10.4	11.9	92.7	93.4	7.3
120921	196.5	36.85	75.90	11.0	9.3	94.1	94.6	5.6
121013	212.9	36.79	75.83	10.2	14.7	87.1	88.3	9.6
121212	259.8	36.20	75.73	10.8	24.4	22.6	33.3	47.1
121219	266.9	36.09	75.69	11.0	27.7	9.7	29.3	70.8
121308	279.8	35.80	75.50	10.9	44.2	-22.6	49.7	117.1
121310	281.5	35.75	75.47	10.9	47.1	-27.4	54.5	120.2
121312	283.3	35.73	75.46	11.0	48.2	-30.1	56.9	121.9
121314	285.1	35.69	75.44	11.1	49.4	-34.3	60.1	124.8
121316	286.8	35.66	75.44	11.3	49.5	-37.2	61.9	126.9
121319	290.3	35.63	75.45	11.5	49.1	-41.1	64.0	129.9
121413	308.5	35.49	75.42	11.5	51.5	-57.0	76.9	137.9
121417	312.0	35.44	75.33	14.5	60.0	-61.9	86.2	135.9

TABLE II.- LIST OF DATA, DEC. 1972 - Continued

(e) Wind Data

Time, Mo/Day/Hr	Chesapeake Light		Oregon Inlet		EB-01	
	Direction	Speed kts	Direction	Speed kts	Azimuth deg.	Speed kts
120118	SW	16	NW	20	263	25
120121	SW	20	NW	15	256	20
120200	SW	20	NW	10	226	21
120203	SSW	22	NW	14	219	20
120206	SW	22	NW	16	251	22
120209	SW	20	NW	16	233	21
120212	*	*	*	*	275	15
120215	W	7	NW	11	272	7
120218	W	6	SW	10	311	3
120221	SE	10	SW	10	214	6
120300	SE	10	SW	10	198	11
120303	S	12	SW	11	213	11
120306	S	15	SW	11	231	16
120309	S	18	SW	11	223	20
120312	SSW	12	SW	15	221	19
120315	SSW	18	SW	15	225	18
120318	SSW	16	SW	15	224	19
120321	S	10	SW	15	242	15
120400	SW	2	SW	5	242	7
120403	SW	10	SW	5	280	5
120406	SW	15	SW	5	288	7
120409	SSW	7	SW	5	45	6
120412	SSE	4	S	3	96	10
120415	*	*	*	*	88	4
120418	SE	4	*	*	145	11
120421	SE	9	SW	10	179	19
120500	SE	10	SW	10	241	12
120503	S	10	SW	10	271	10
120506	S	10	SW	15	250	10
120509	SSW	10	SW	15	280	11
120512	SSW	10	SW	15	292	6
120515	S	10	SW	10	164	11
120518	SSE	10	SW	8	197	10
120521	SSE	12	SW	8	174	15
120600	SE	18	SW	8	166	18
120603	SE	10	SW	7	167	22
120606	SSE	10	SW	10	170	23
120609	SSE	18	*	*	143	28
120612	SSE	15	SSE	10	164	35
120615	SSE	15	SW	15	164	34
120618	SE	19	SSW	15	161	37
120621	SSE	8	SW	18	170	38

* No data.

TABLE II.- LIST OF DATA, DEC. 1972 - Continued

(e) Wind Data - Continued

Time, Mo/Day/Hr	Chesapeake Light		Oregon Inlet		EB-01	
	Direction	Speed kts	Direction	Speed kts	Azimuth deg	Speed kts
120700	S	12	SW	18	239	28
120703	SW	13	SW	15	273	23
120706	NW	30	SW	15	315	26
120709	NW	30	NE	25	346	28
120712	NNW	28	NE	25	6	27
120715	NNW	26	NE	25	3	24
120718	NNW	18	NE	25	11	21
120721	NNE	18	NE	25	20	18
120800	NE	18	NE	20	31	13
120803	N	20	NE	20	2	14
120806	NE	16	NE	10	113	8
120809	NNE	10	NE	15	112	13
120812	NNE	10	NE	15	119	13
120815	N	10	NE	10	140	16
120818	WNW	7	SW	10	150	16
120821	SE	13	SE	10	153	21
120900	SE	22	SE	10	163	21
120903	SSE	16	SE	12	160	27
120906	NW	8	SE	15	187	27
120909	W	10	SW	10	201	26
120912	S	10	SW	15	211	24
120915	SSW	10	SW	10	217	27
120918	S	18	SW	15	218	22
120921	SSW	14	SW	15	218	19
121000	SSW	14	SW	15	229	20
121003	SSW	7	SW	15	226	18
121006	SE	6	SW	15	203	19
121009	SW	6	SSW	12	230	21
121012	S	10	SW	15	231	20
121015	S	15	SW	18	201	24
121018	S	22	SW	15	214	27
121021	SW	14	SW	15	222	25
121100	SW	14	SW	16	231	18
121103	SSW	10	SW	15	242	23
121106	W	17	SW	15	317	15
121109	NNW	20	SW	15	354	24
121112	NNW	22	NE	18	349	19
121115	N	20	NE	20	1	7
121118	NNW	10	NE	20	346	17
121121	N	11	NE	20	2	12

TABLE II.- LIST OF DATA, DEC. 1972 - Concluded

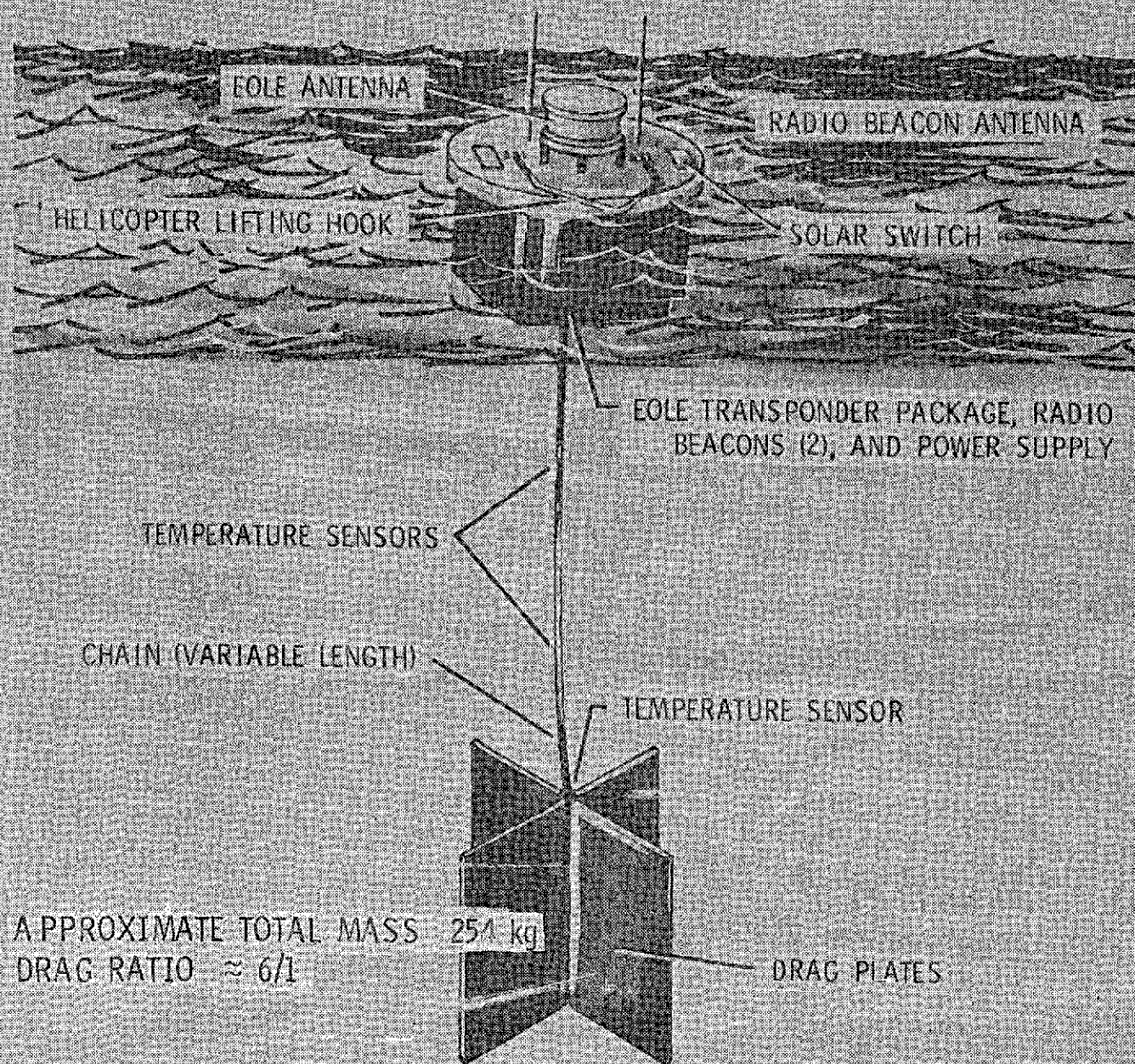
(e) Wind Data - Concluded

Time, Mo/Day/Hr	Chesapeake Light		Oregon Inlet		EB-01	
	Direction	Speed kts	Direction	Speed kts	Azimuth deg	Speed kts
121200	N	10	NE	20	14	11
121203	NNE	10	NE	20	25	15
121206	NNE	10	NE	20	25	15
121209	NNE	10	NE	20	64	11
121212	NNE	20	NE	20	118	14
121215	NE	20	NNE	15	137	17
121218	NNE	13	NNE	15	156	20
121221	NNE	13	NE	22	162	25
121300	NNW	10	NE	20	219	19
121303	W	10	NE	5	218	24
121306	SSW	8	NE	10	226	26
121309	S	10	NE	2	218	26
121312	SSW	12	NE	5	260	25
121315	SW	15	NE	5	242	20
121318	SW	10	W	10	286	14
121321	W	10	SW	12	354	14
121400	N	14	SW	10	9	17
121403	N	22	*	*	23	15
121406	NNE	10	*	*	39	12
121409	NNE	20	*	*	95	15
121412	NNE	20	*	*	44	13
121415	NNE	16	NE	7	20	22
121418	NNW	16	NE	15	*	*
121421	NNW	17	NE	18	*	*

*
No data.

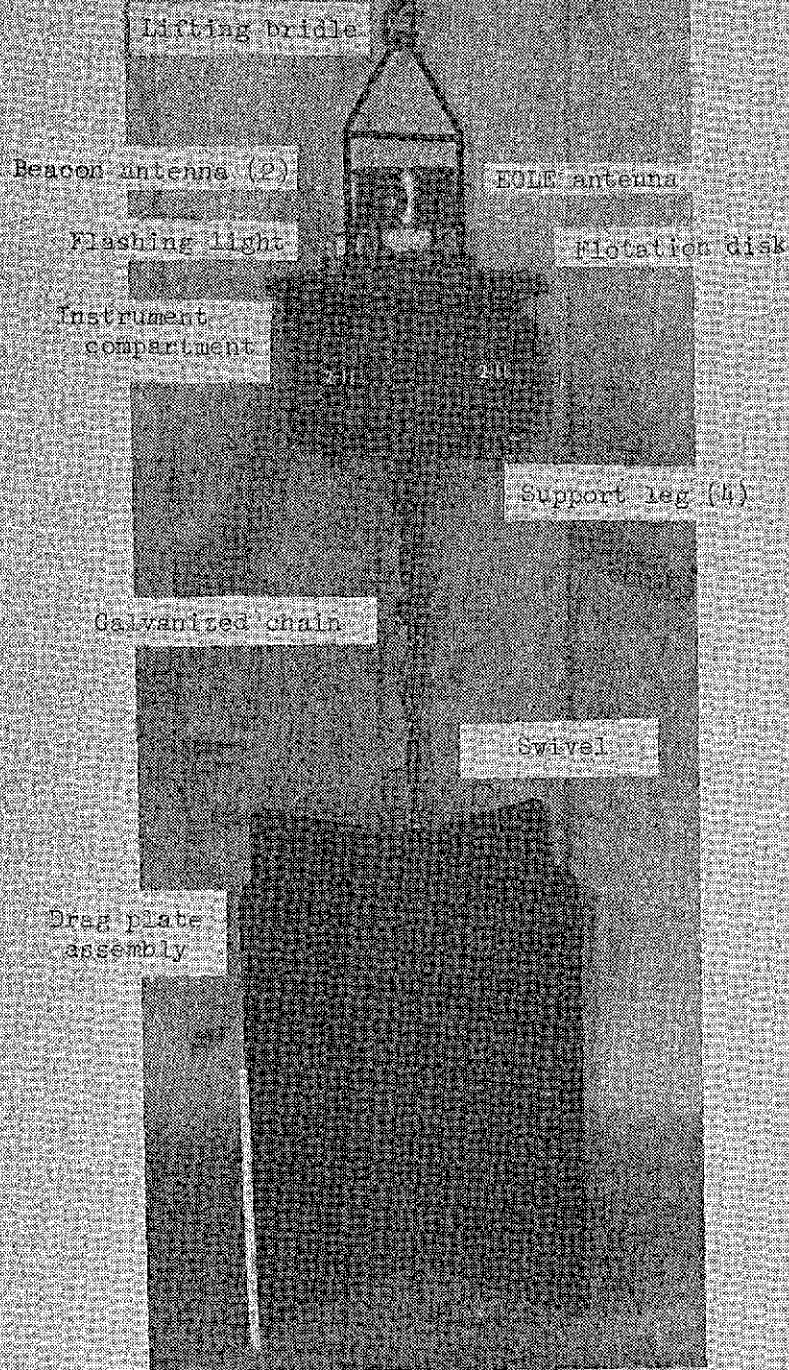
TABLE III - TEMPERATURE DATA ACCURACY

Channel Number	Actual Temperature, °C	Measured Temperature, °C	Δ Temperature (error), °C
#1	10.009	10.162	+.153
		10.024	+.015
		10.162	+.153
		10.162	+.153
		10.302	+.293
		10.024	+.015
		10.302	+.293
#2	12.007	12.001	-.006
		11.881	-.126
		11.998	-.008
		11.864	-.143
		11.998	-.008
		12.116	+.109
		12.130	+.123
#3	21.977	11.998	-.008
		21.910	-.067
		21.800	-.177
		21.907	-.070
		21.907	-.070
		21.907	-.070
		22.013	-.036
#4	13.953	21.807	-.170
		13.774	-.179
		13.889	-.064
		13.774	-.179
		14.002	+.049
		13.889	-.064
		14.002	+.049
		13.889	-.064
		14.002	+.049
		14.002	+.049

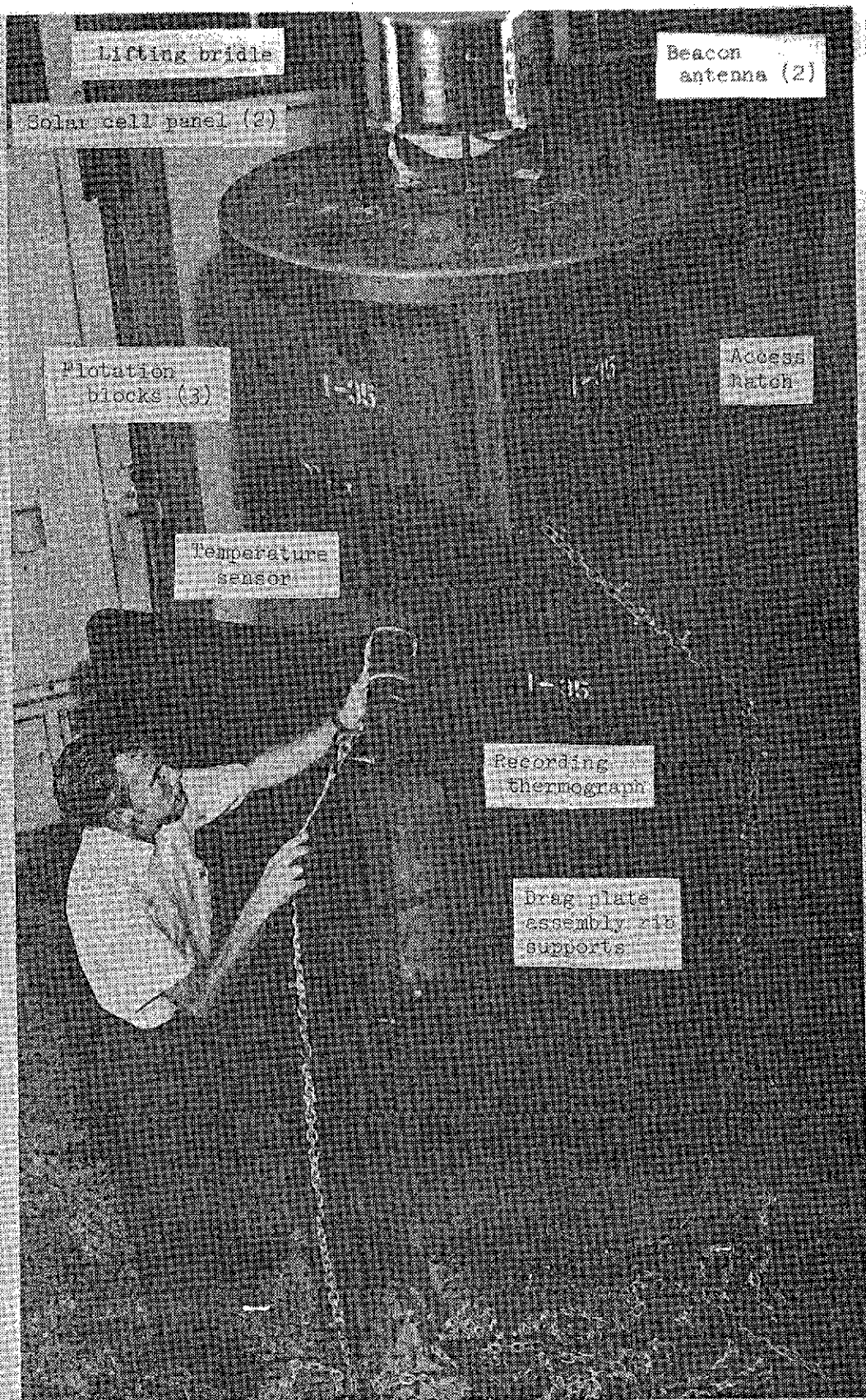


(a) Artist sketch of buoy system.

Figure 1. - Buoy system sketch and photographs.



(b) Photograph of the buoy system
Figure 1.- Continued



(c) Photograph of the buoy system.
Figure 1.- Concluded.

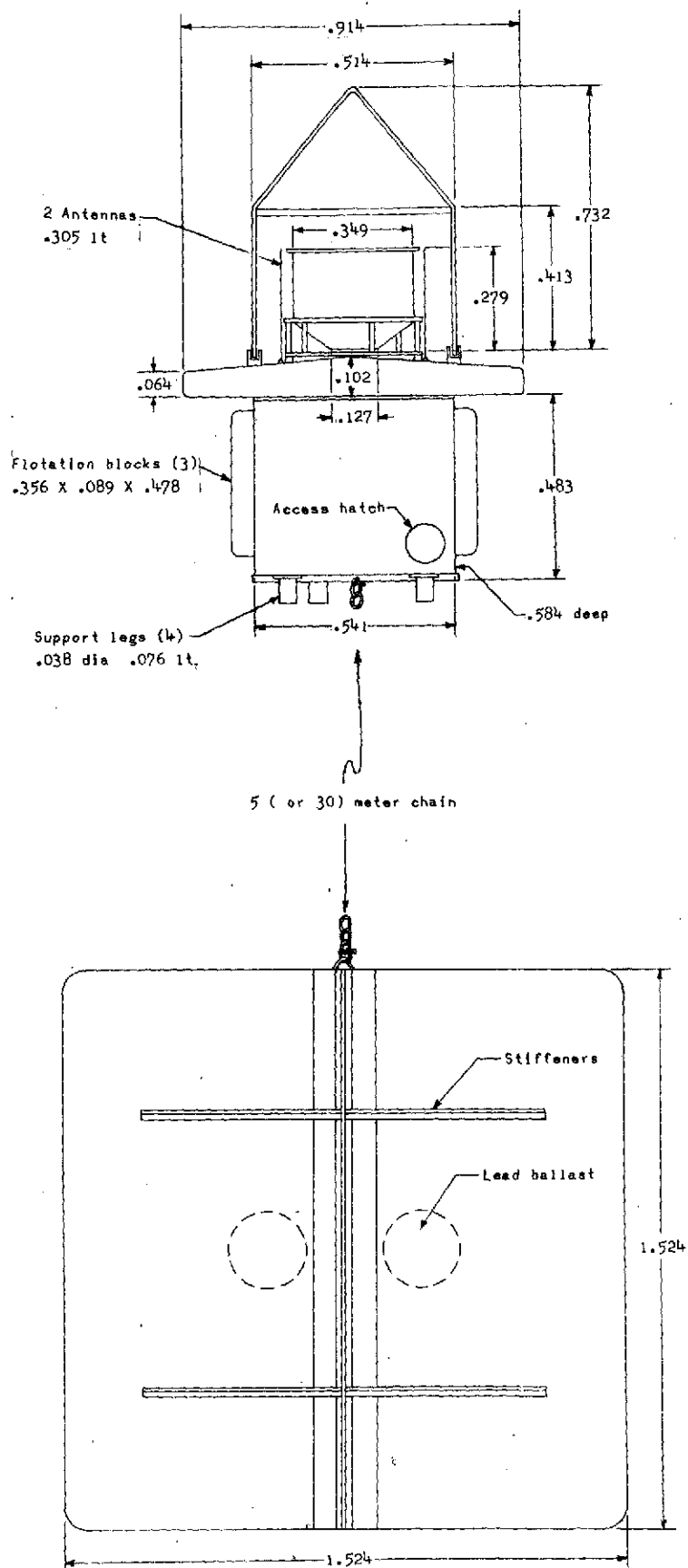


Figure 2.- Sketch of the buoy system. (All dimensions in meters.)

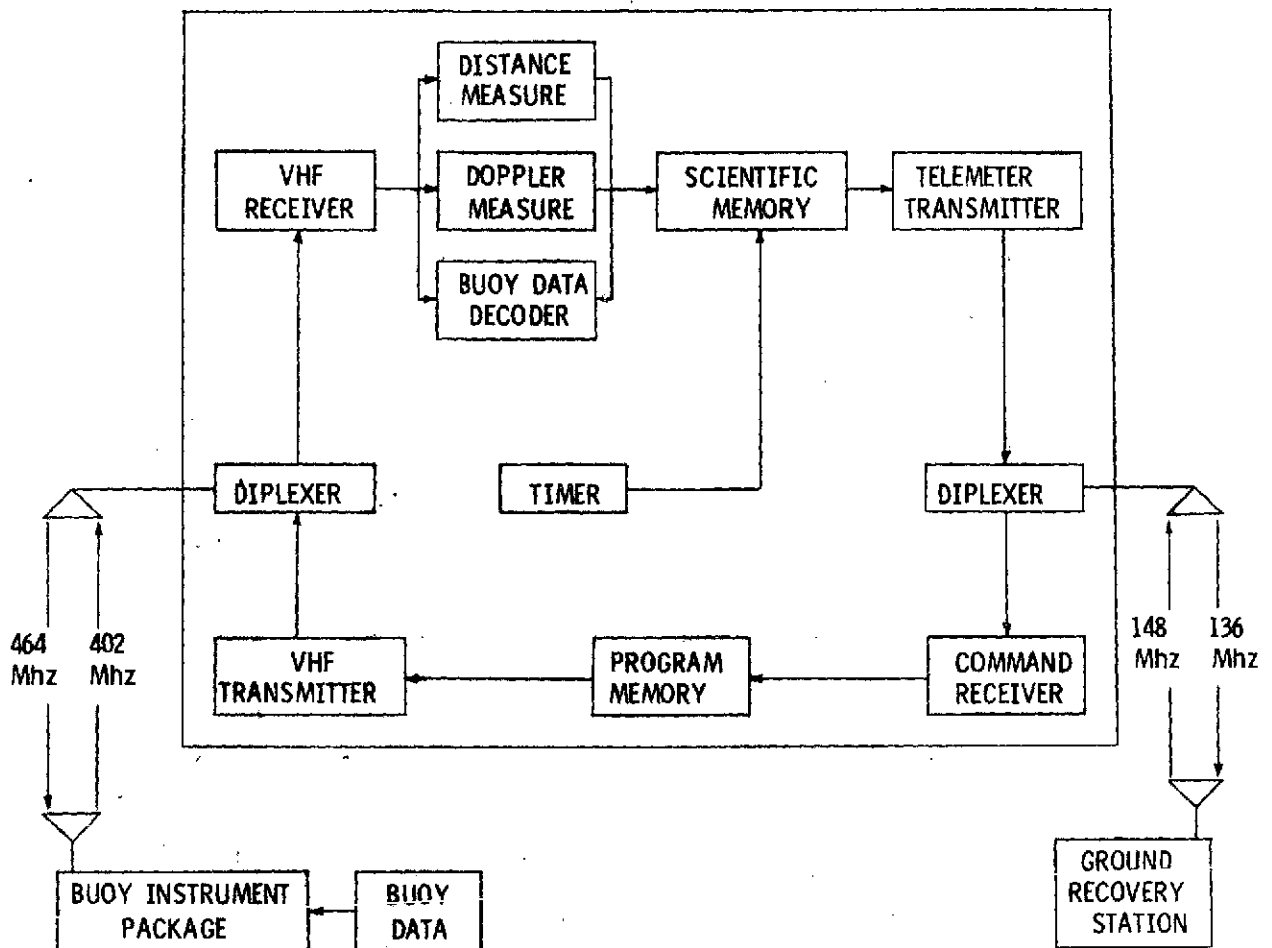
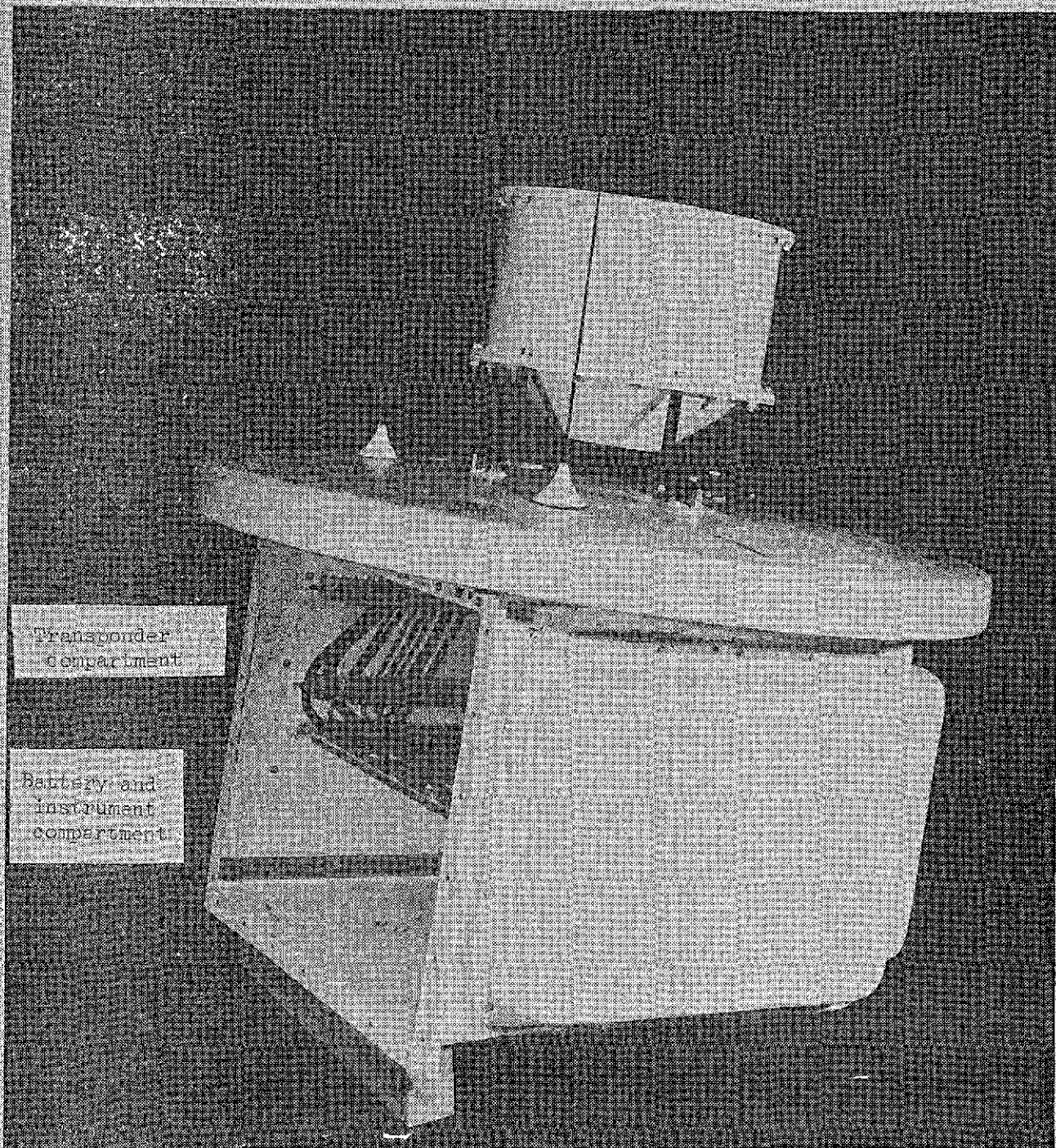
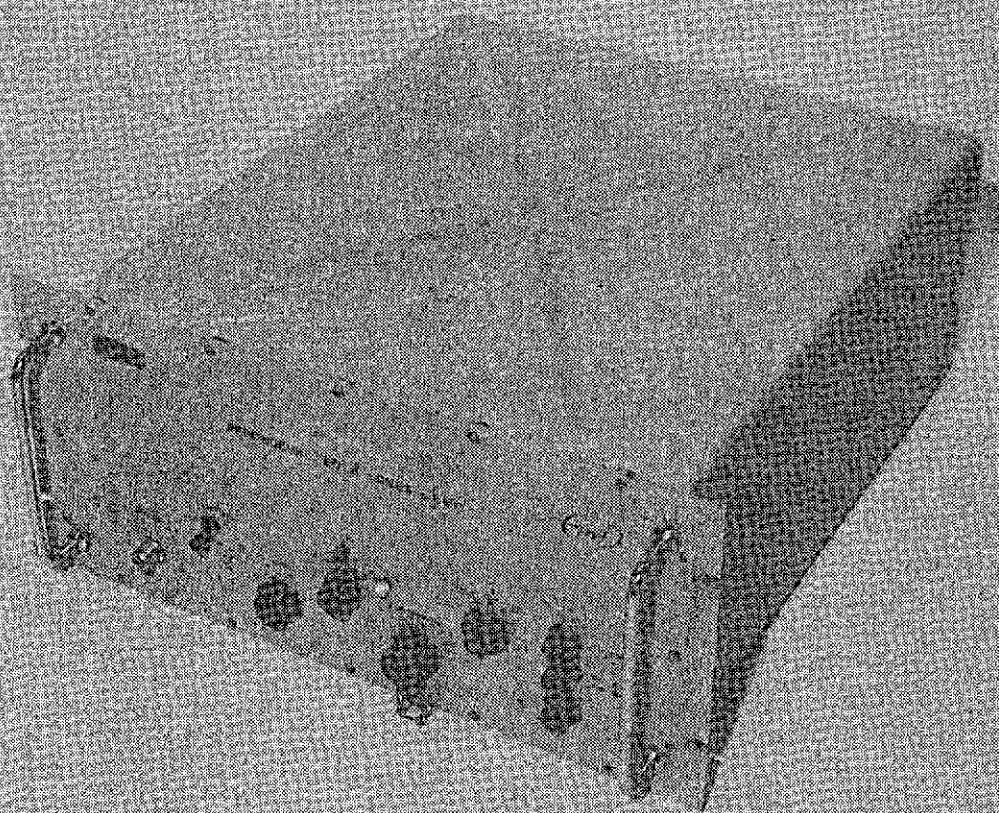


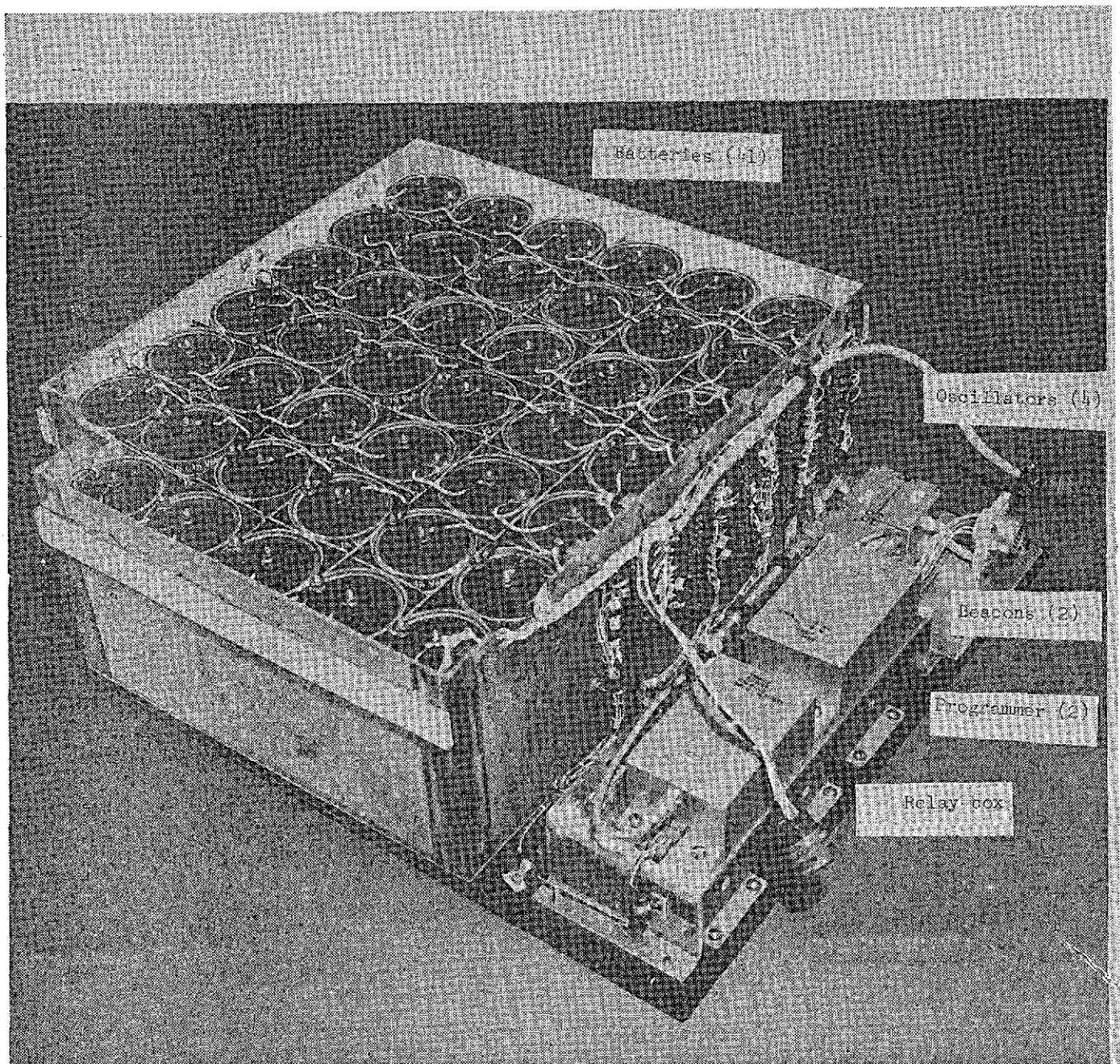
Figure 3. - Buoy-satellite-ground station communications concept.



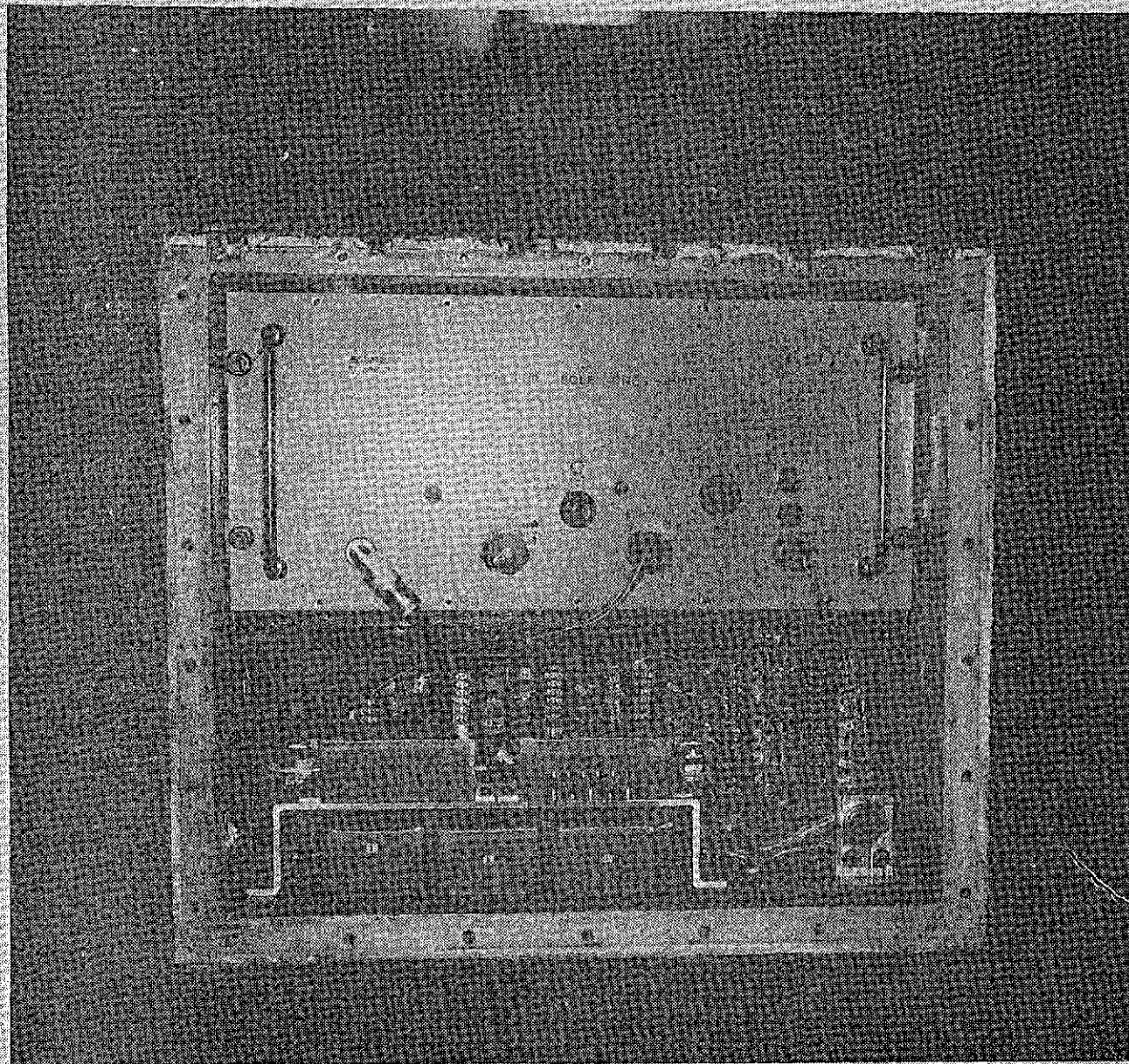
(a) Empty instrument compartment
Figure 4.- Photographs of the instrument compartment and components.



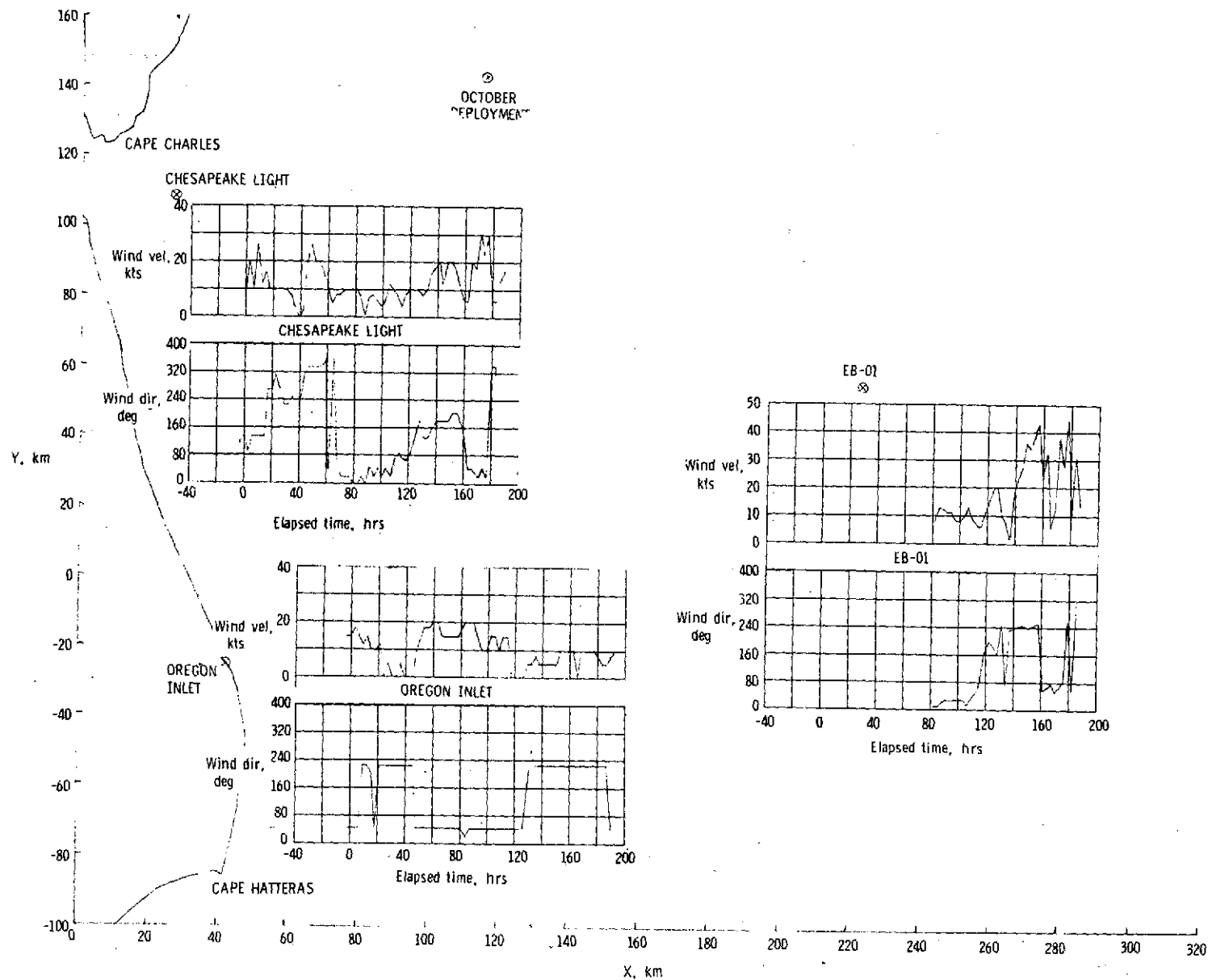
(b) French E01A transponder
Figure 4. - Continued.



(c) Batteries and instruments
Figure 4-2 Continued.

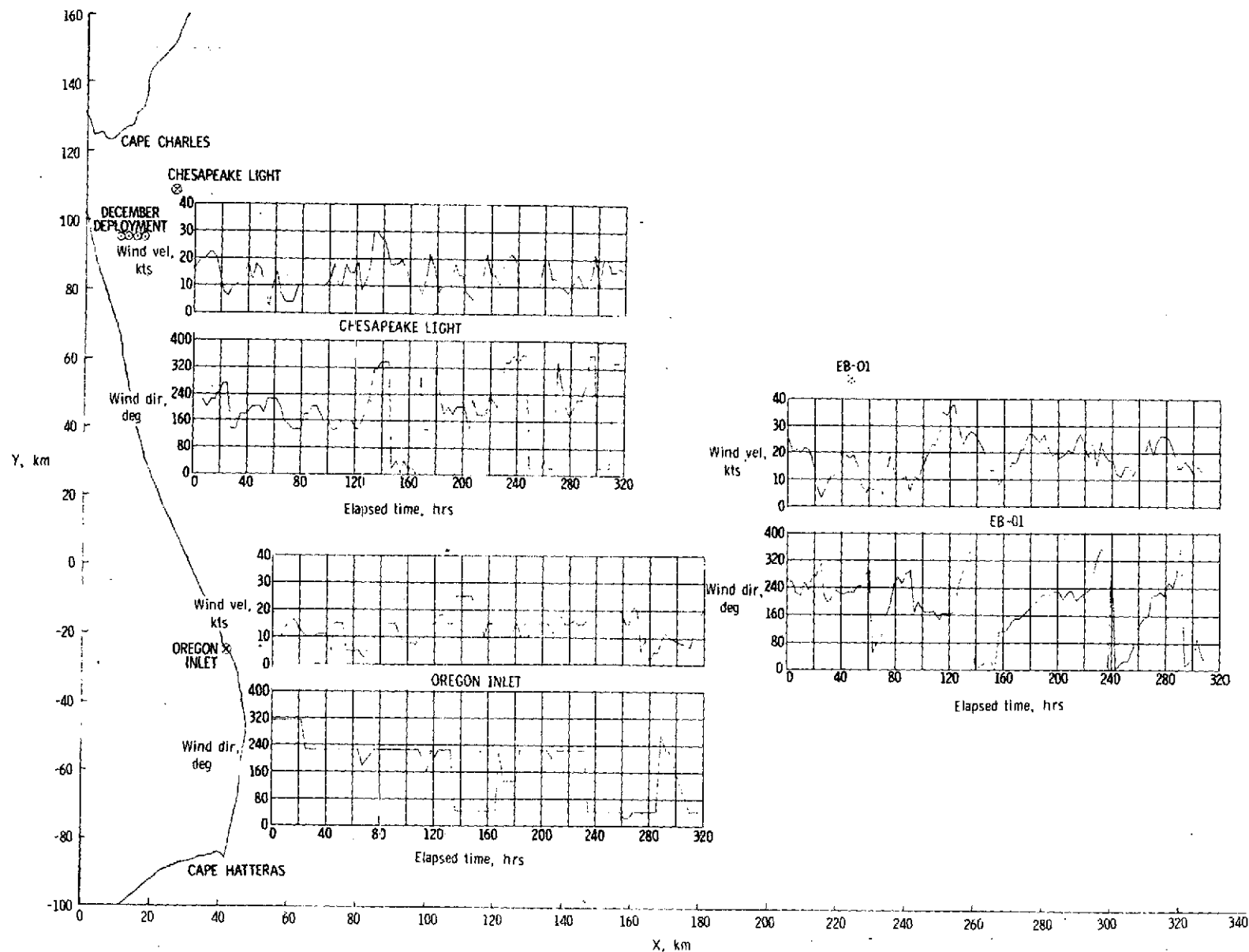


(a) Instrument compartment with components installed
Figure 4.- Concluded.



(a) October-November Mission.

Figure 5. - Deployment positions and histories of the wind speed and direction at Chesapeake Light, EB-01, and Oregon Inlet.



(b) December Mission.

Figure 5. - Concluded.

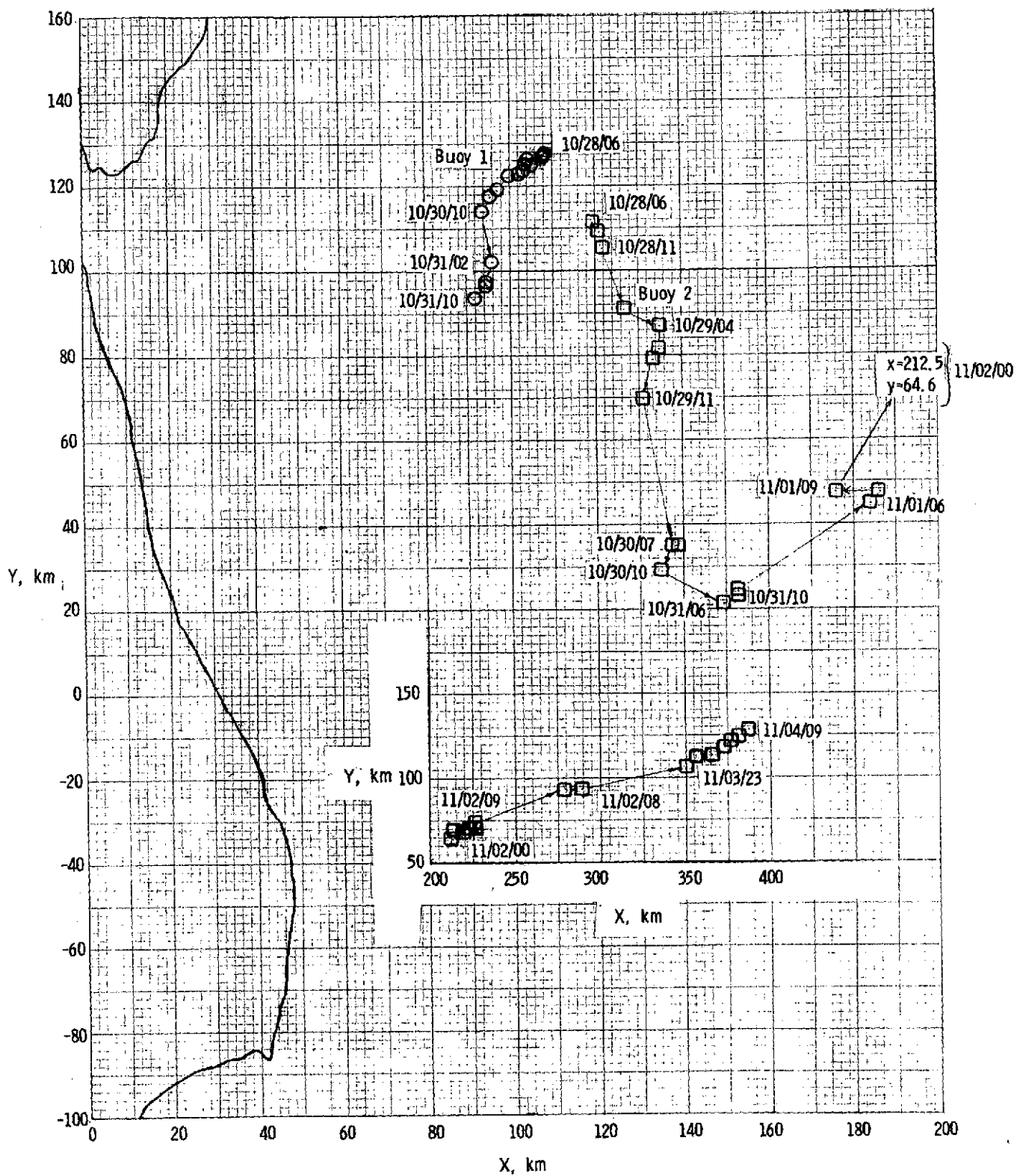
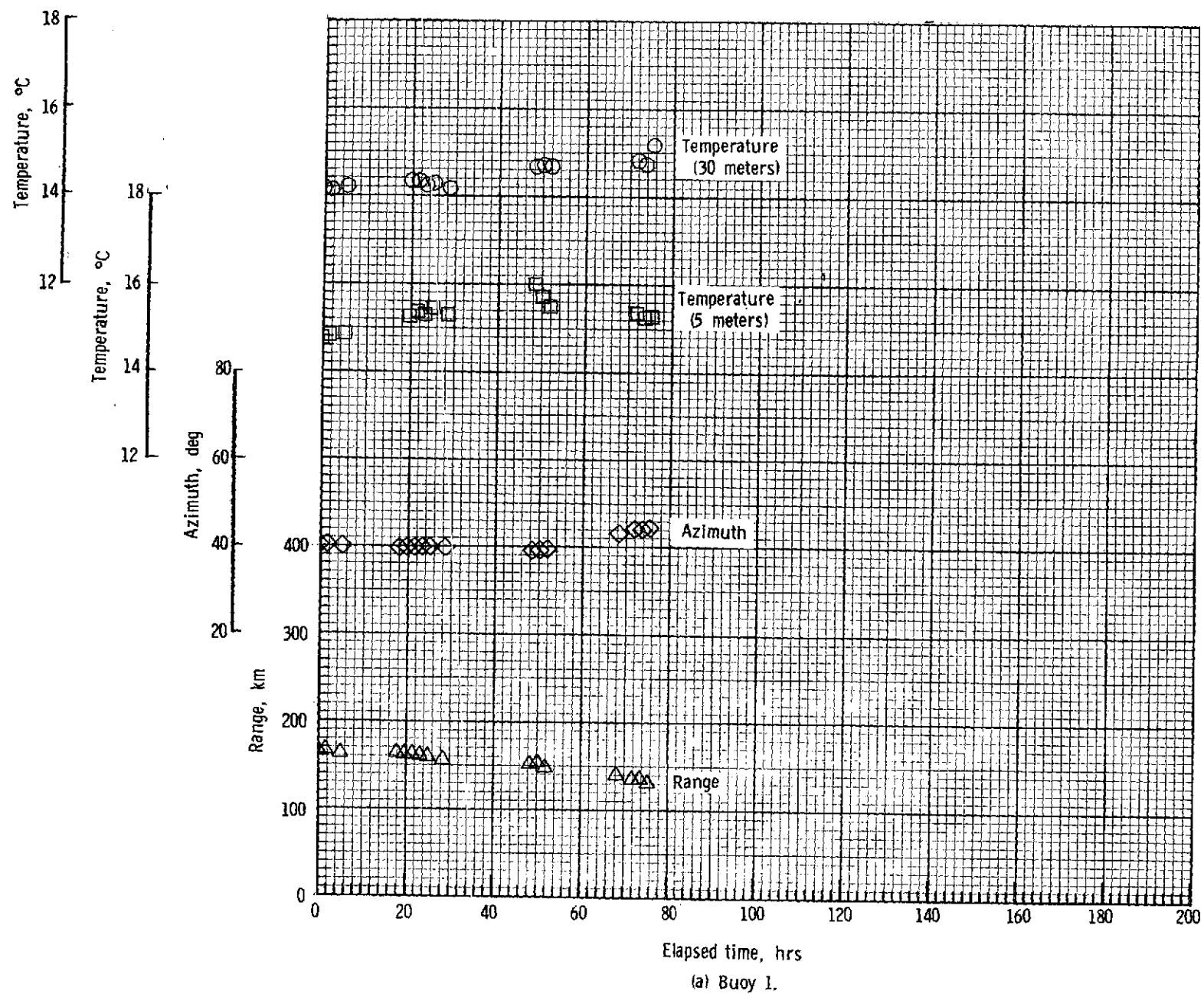
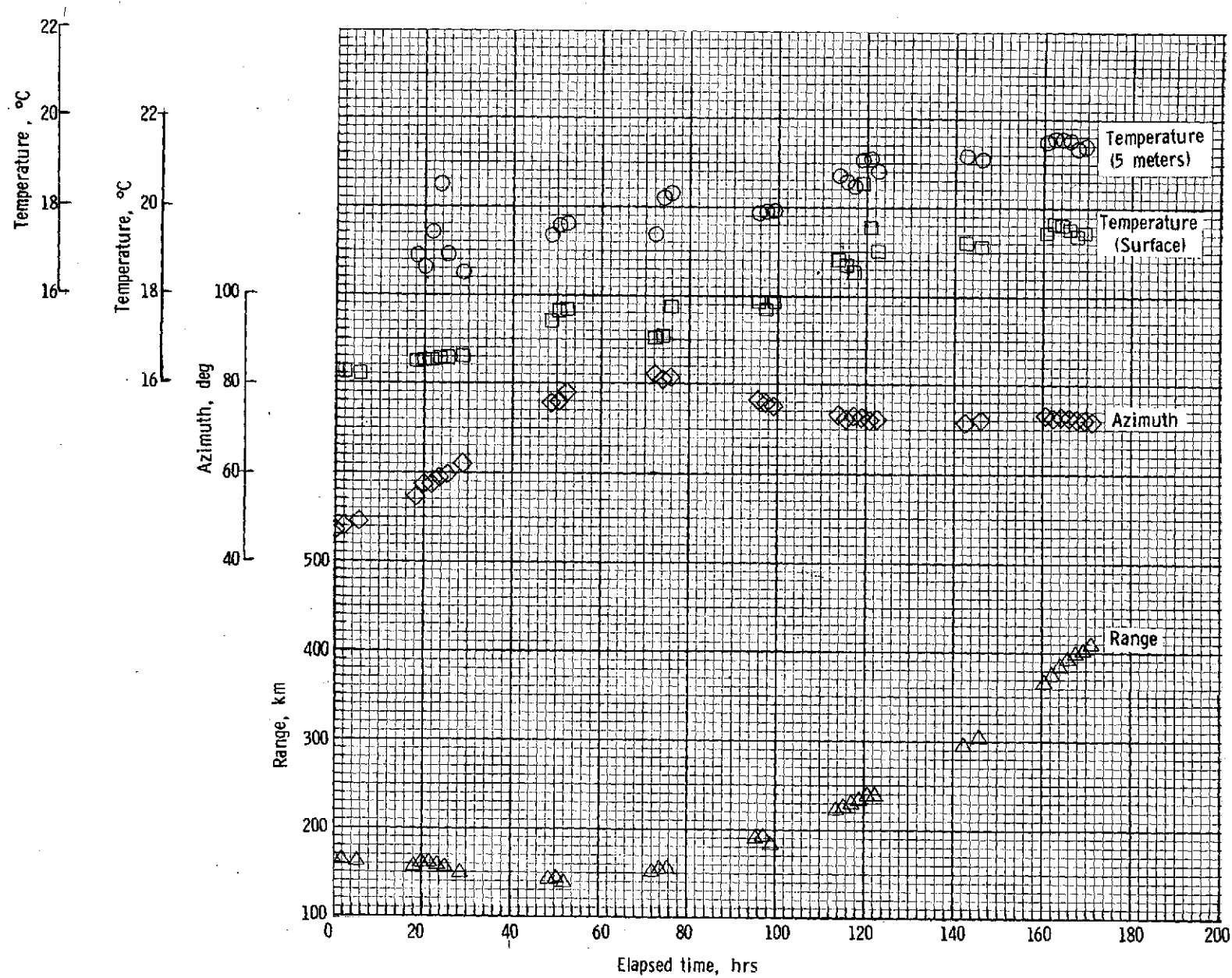


Figure 6. - Buoy trajectories for October - November 1972.



(a) Buoy 1.
Figure 7. - Time histories of the temperature and position data, Oct - Nov 1972.



(b) Buoy 2.

Figure 7. - Concluded.

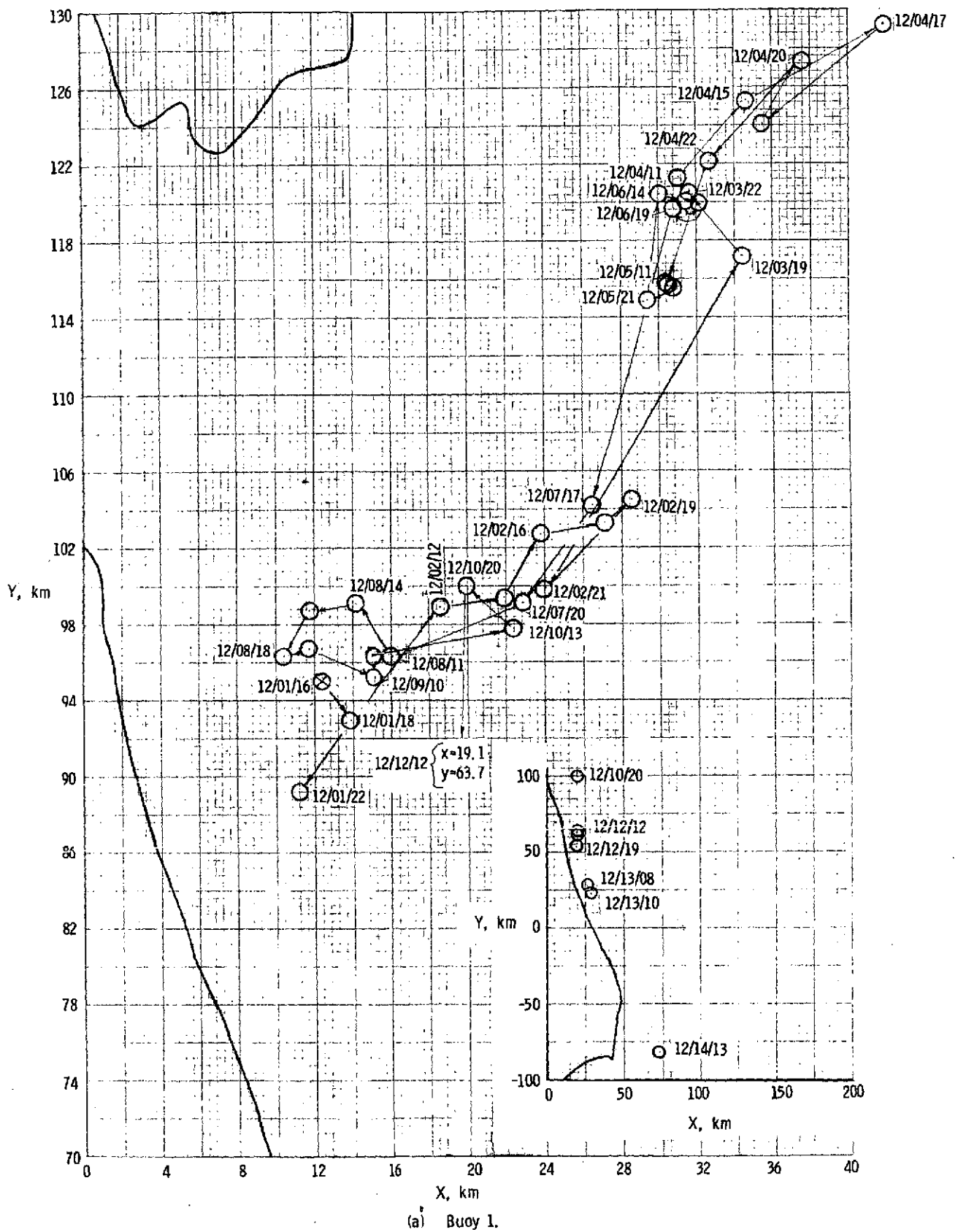
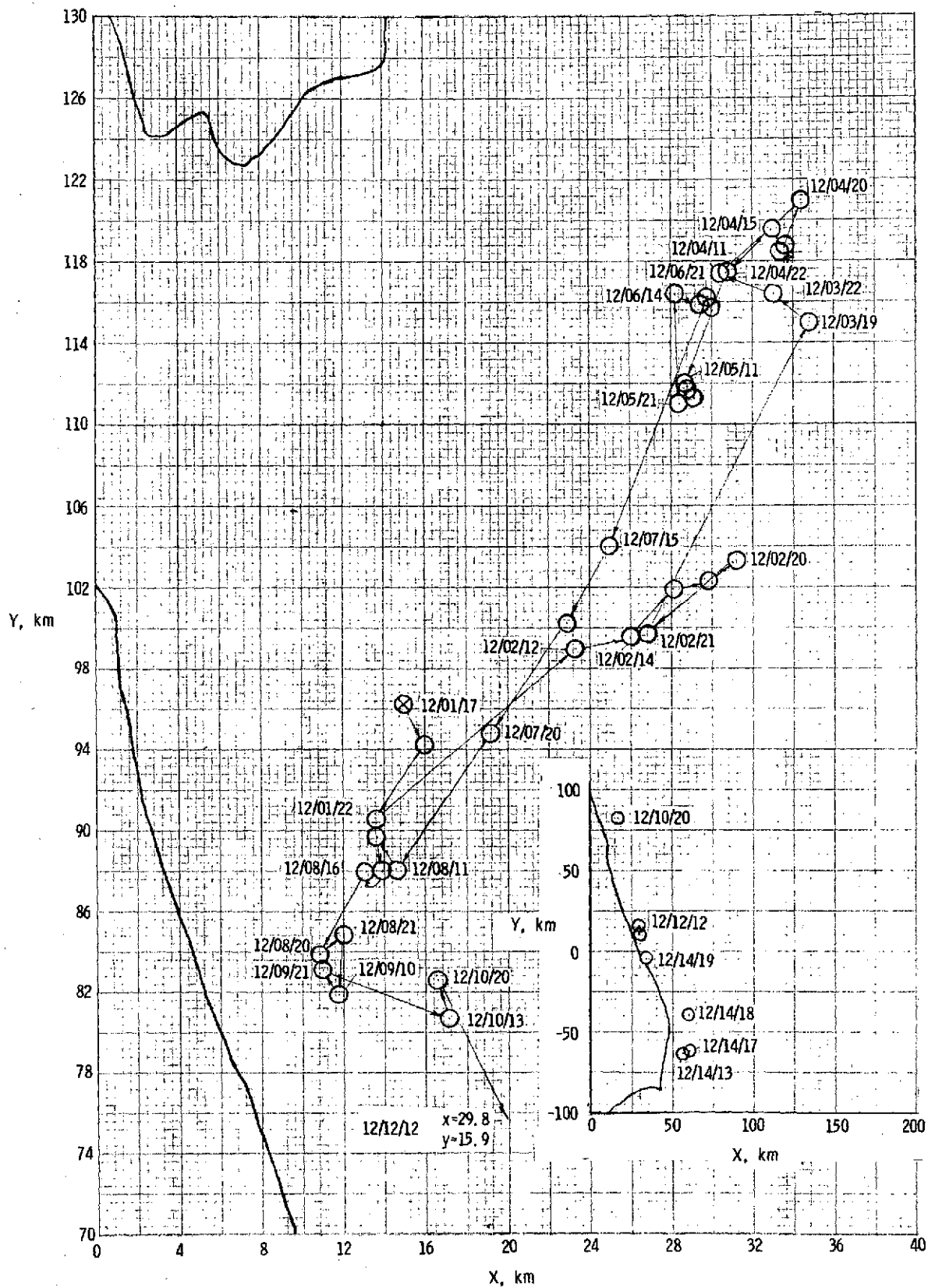
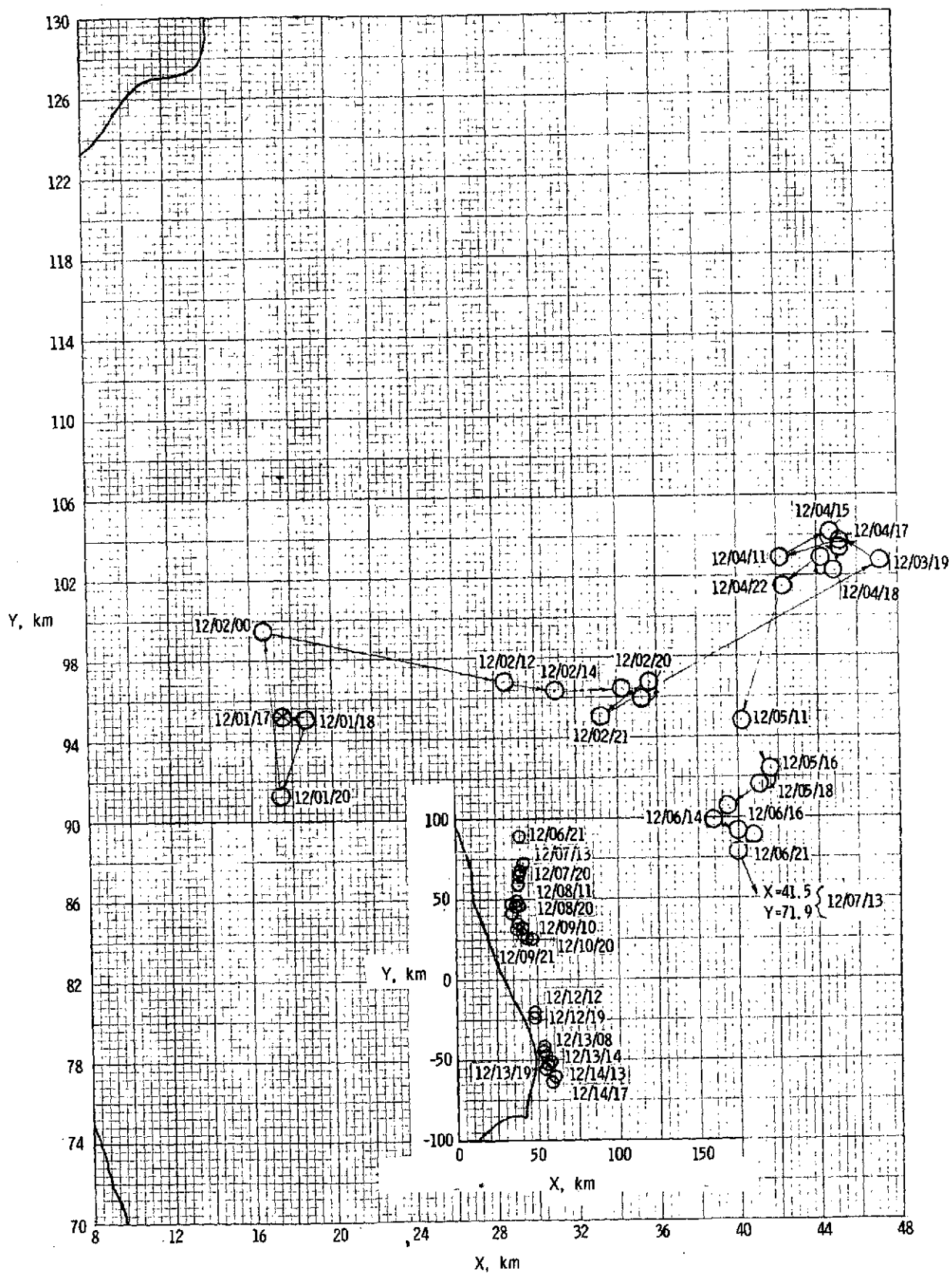


Figure 8. - Buoy trajectories for December 1972.



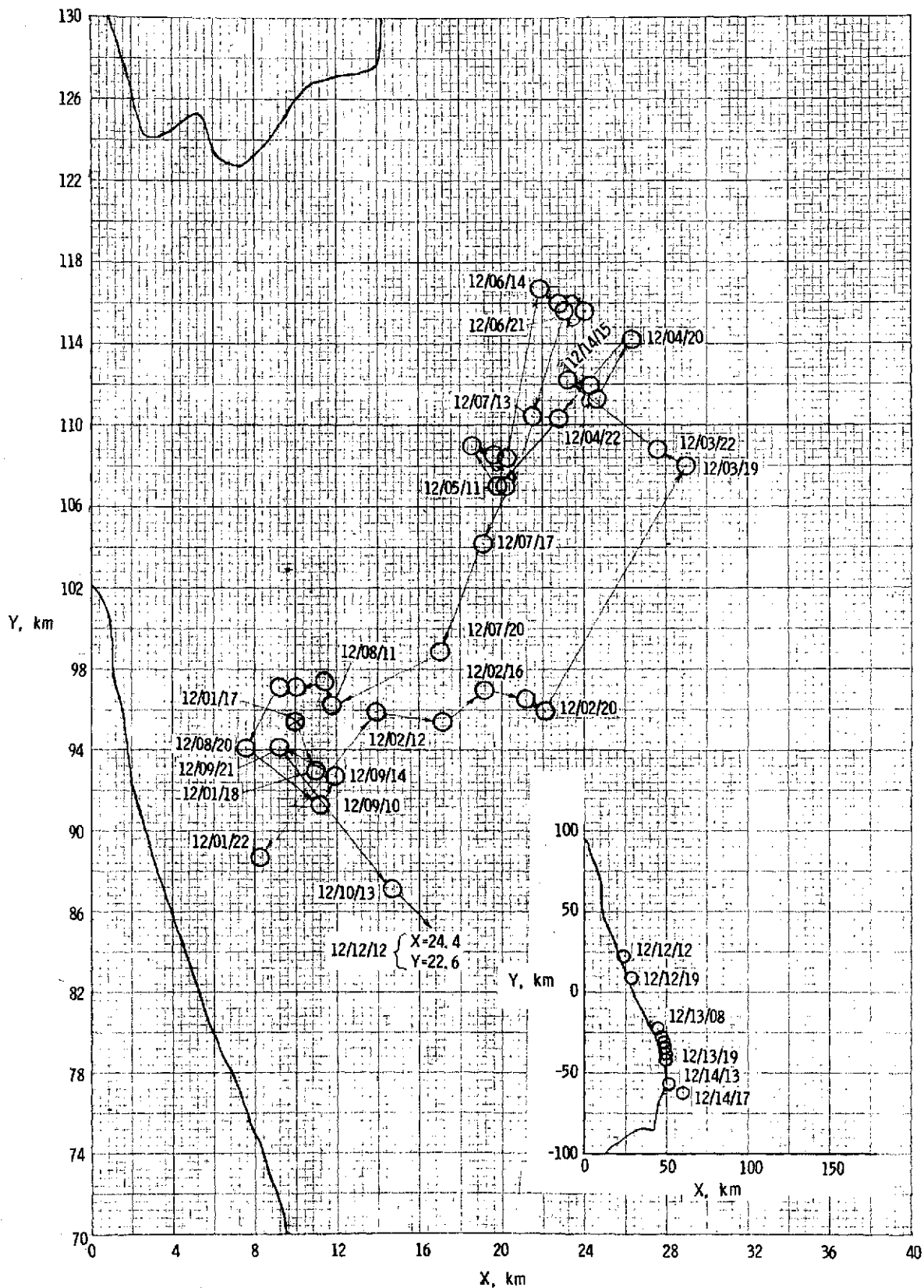
(b) Buoy 2.

Figure 8. - Continued.

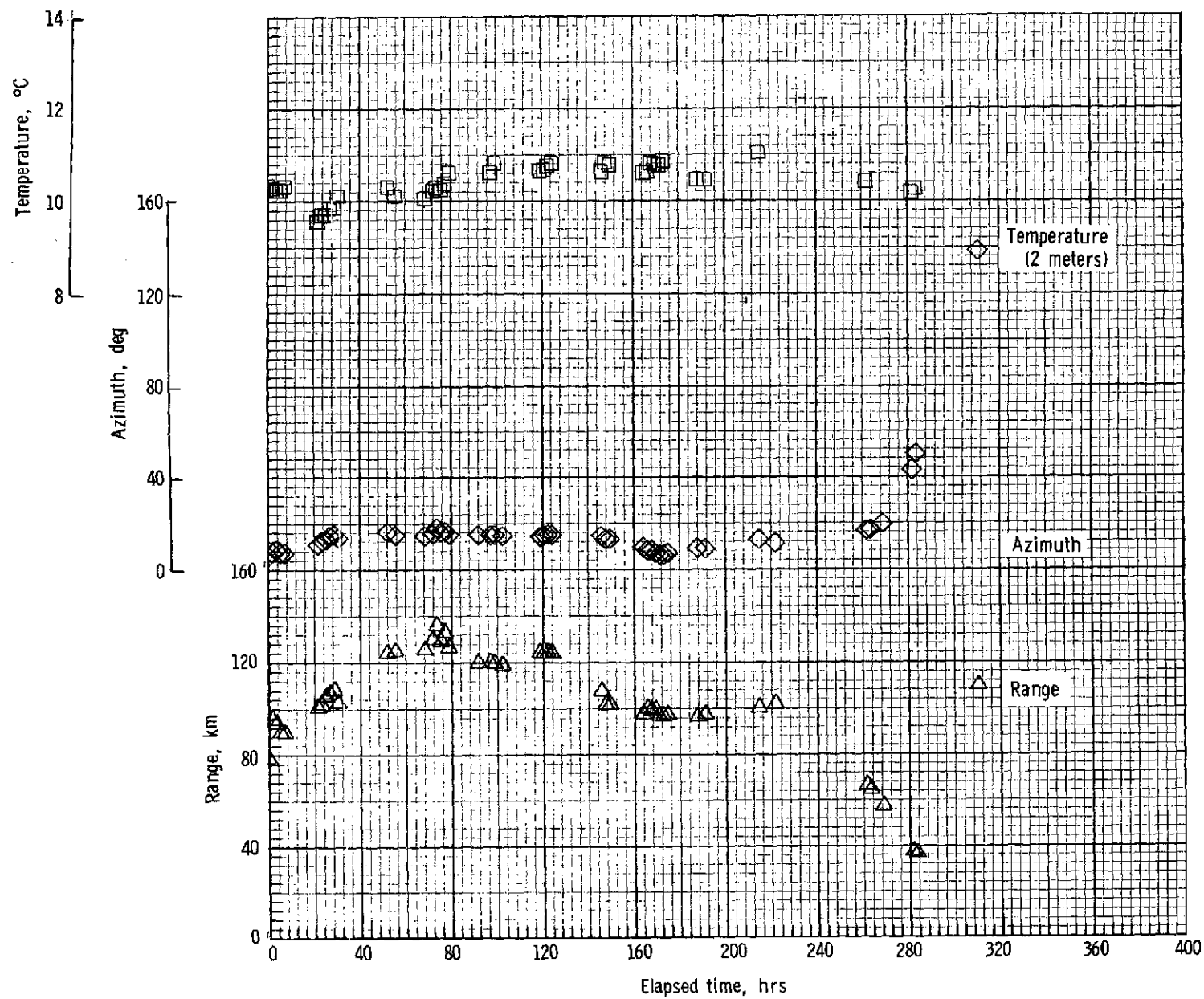


(c) Buoy 3.

Figure 8. - Continued.

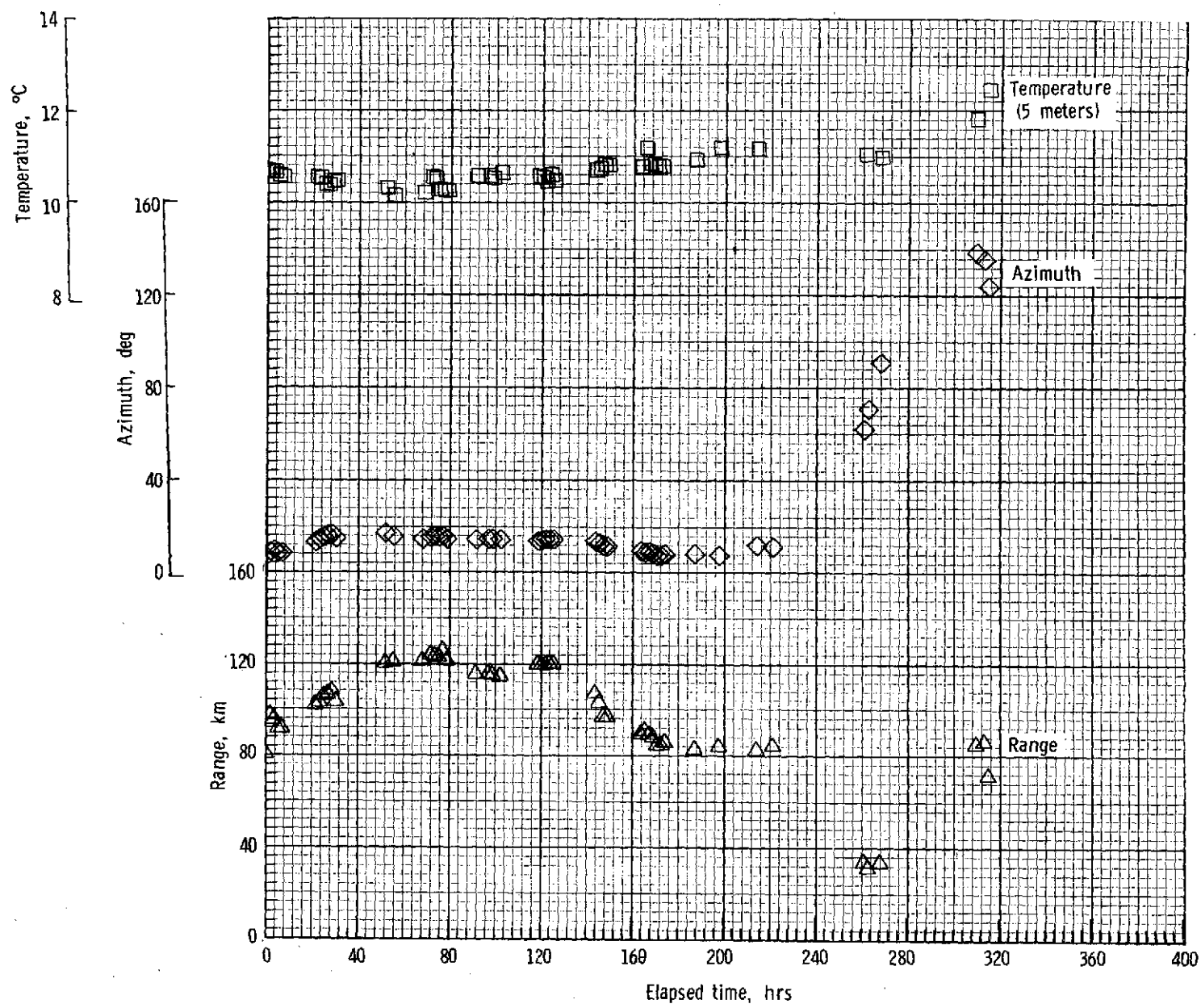


(d) Buoy 4.
Figure 8. - Concluded.



(a) Buoy 1.

Figure 9. - Time histories of the position and temperature data, Dec. 1972.



Elapsed time, hrs

(b) Buoy 2.

Figure 9. - Continued.

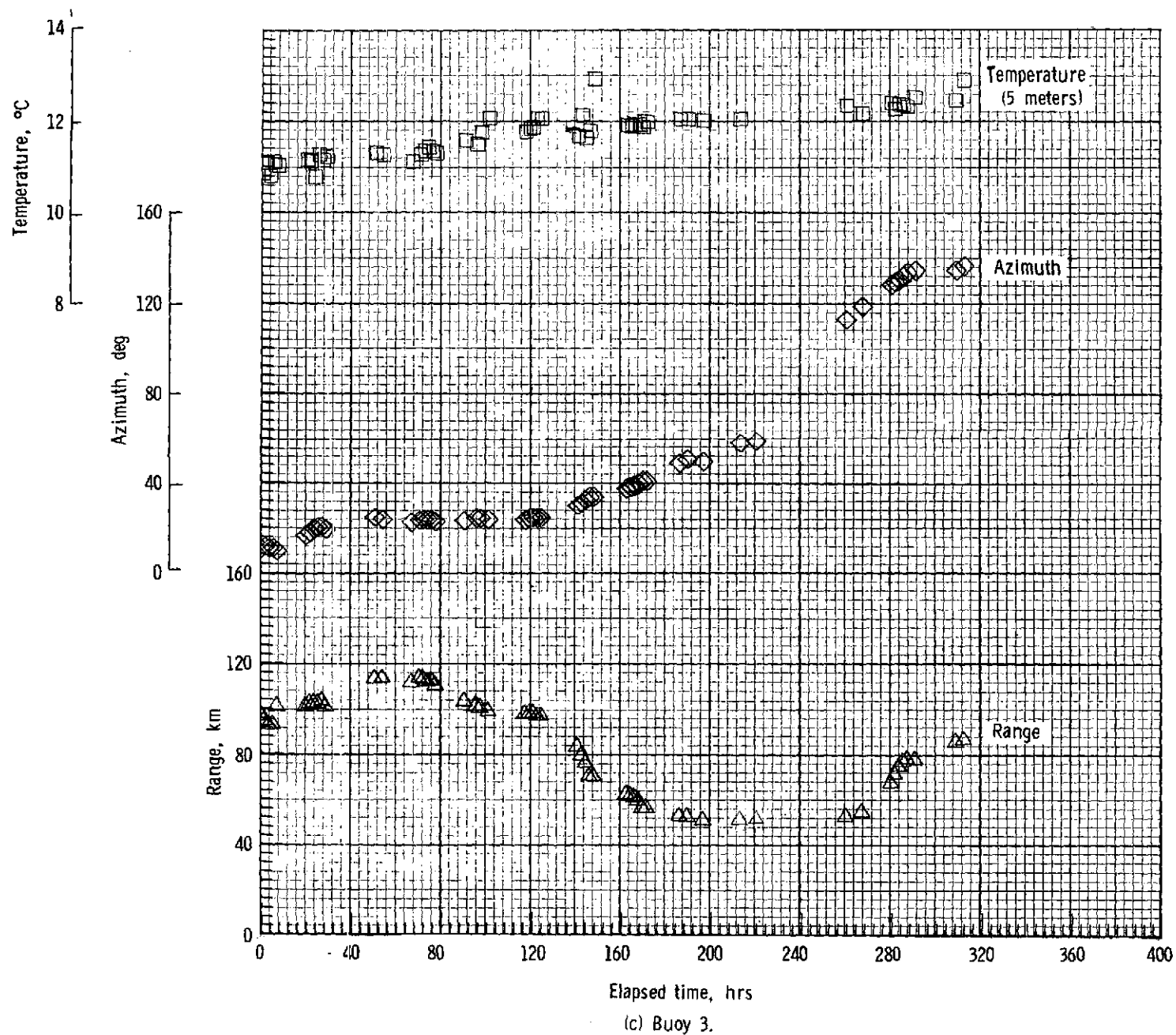
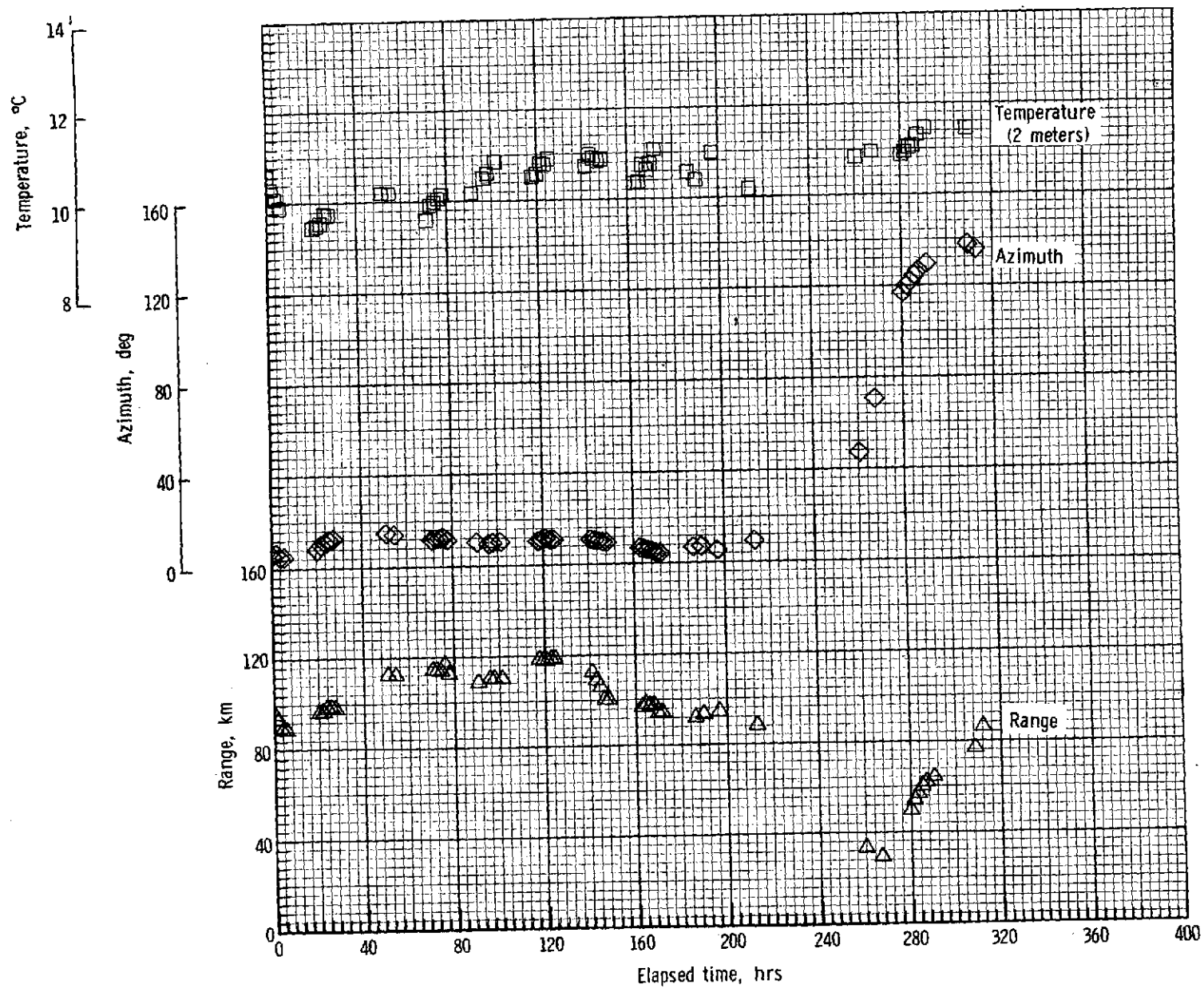
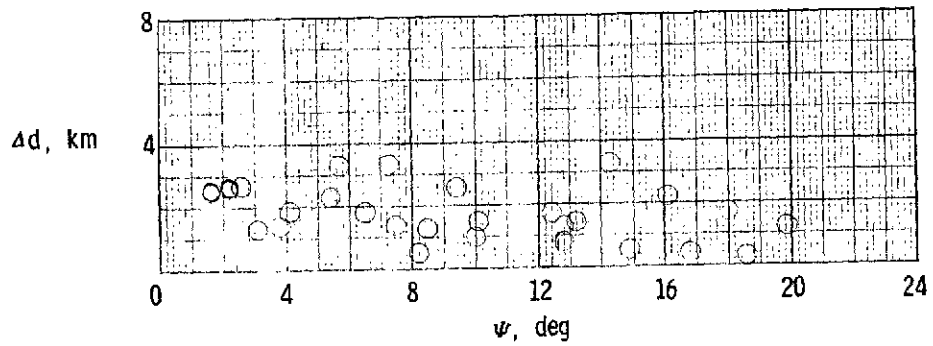


Figure 9. - Continued.

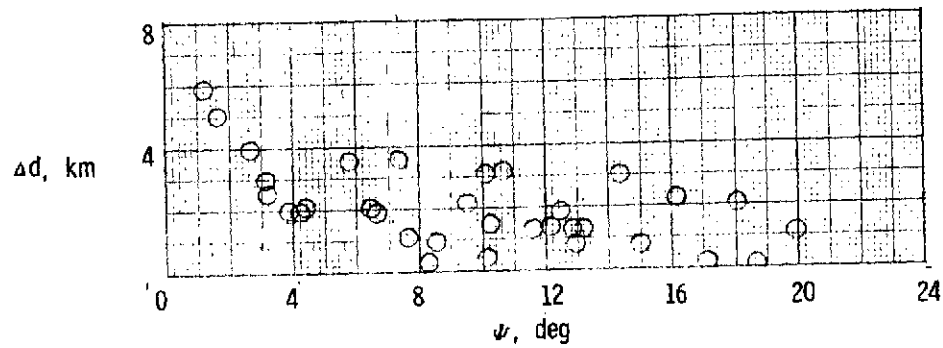


(d) Buoy 4.

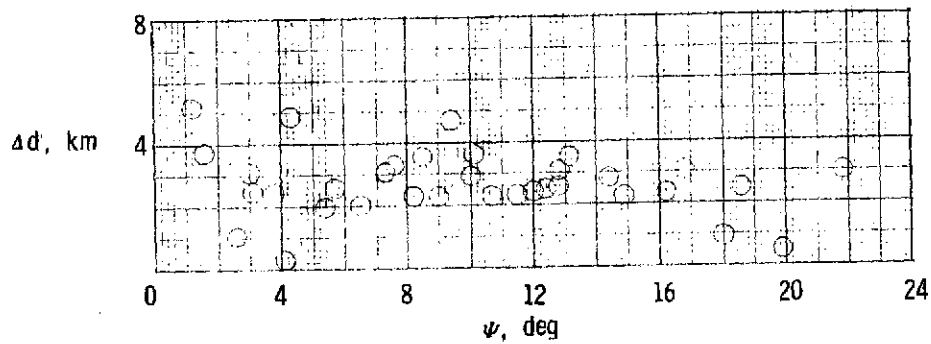
Figure 9. - Concluded.



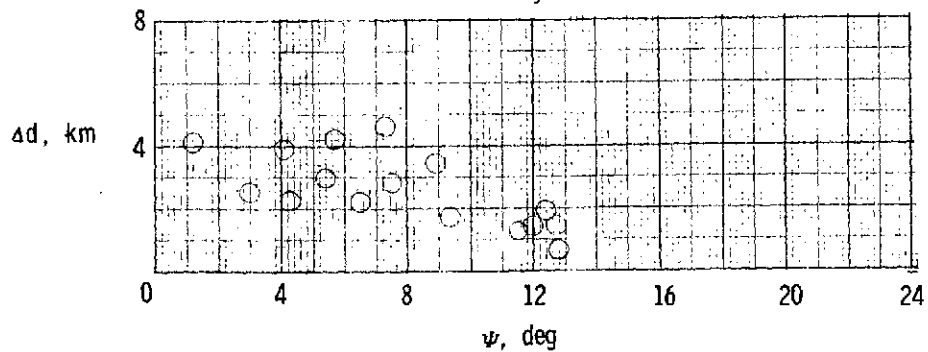
(a) Buoy 1.



(b) Buoy 2.



(c) Buoy 5.



(d) Buoy 6.

Figure 10. - Errors in Buoy locations as a function of ground track distance.

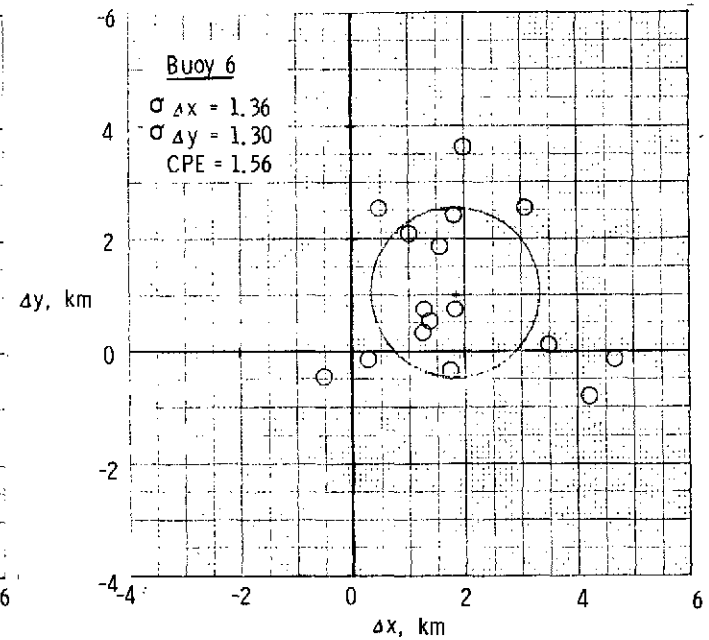
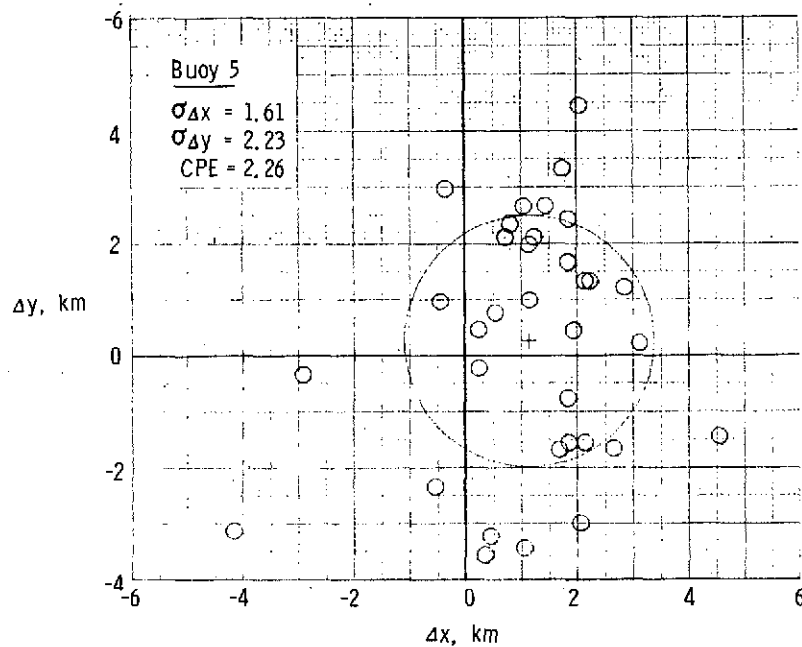
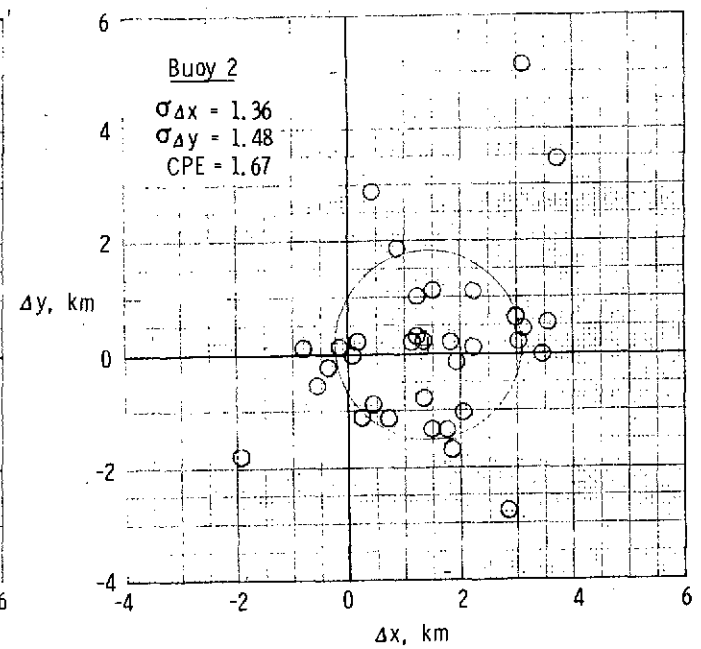
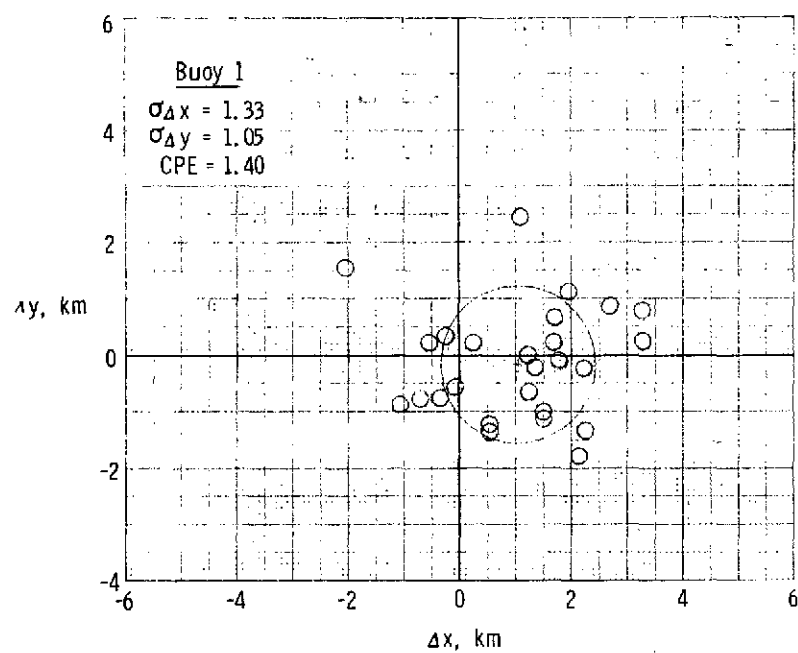


Figure 11. - Systematic and random errors associated with the position data.